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Bell Laboratories

RECORD

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Bell Laboratories **RECORD**

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Contents

Cover *J. B. Howard inspecting samples of polyethylene removed from artificial weathering machine. The device is one of many used in testing materials for underseas cables (see p. 249).*

Experimental equipment under research study at Bell Laboratories: these units — termed ESSEX for "experimental solid-state exchange" — simulate a portion of system built for exploratory investigation of possibilities for integrating transmission and switching using PCM techniques.

People take turns using a library book for two-week periods. But in a more subtle application of time sharing, the same people might take turns using telephone equipment for periods measured in millionths of a second. The result may someday be major economies and important improvements in service.

W. D. Lewis

THE IDEA OF TIME SHARING

"The sum of wisdom is that time is never lost that is devoted to hard work."
—EMERSON

The idea of time sharing is surely as old as the idea of time itself. Caesar's army could not go to Gaul as a single body, but his legions, by marching in a well-planned sequence, could time-share the Roman highways, bridges and campsites. The old ideas of "rent" in real estate and of "interest" in finance are quantitative expressions of the idea of time sharing. They make it possible for different users to share property and money if their use is at different times.

As old as this idea is, electrical communication is exploiting it in more exhaustive, more subtle, and better understood ways than ever before. Furthermore, schemes now only in the research laboratory, on the drawing boards, or in technical memoranda will carry this exploitation much further. They provide a revolutionary concept for a modern telephone plant.

Two kinds of time sharing are important in communication science. One is simply the *sequential* use of the same facility by different users. For example, a telephone trunk is used successively by different conversations. A No. 5 Crossbar marker is employed successively to establish different connections. The other time-sharing idea is new in voice transmission and is more subtle. This is the principle of *time division.* Implemented by high-speed electronic devices, this principle is opening up an abundant array of opportunities in switching and transmission.

Trunking, Queueing, and Common Control

"There is a time for everything — a time to set up, and a time to pull down. . . .—MACAULAY

The idea of sequential use or of taking turns is already applied widely throughout the communications industry. Its possibilities and limitations have been explored by substantial blocks of theory, some of it quite intricate. For example, trunking tables are commonly used by telephone engineers to establish just what percentage of the total time can safely be used in a group of

A. C. Beck adjusting circular waveguide lines at the Holmdel, N. J., Laboratory. Waveguide systems are among many that can use time-sharing.

trunks of specified size. From intuition, perhaps, as well as from the tables, certain broad rules can be stated. As we put common facilities, trunks for example, in larger groups, then it is possible to use them a larger fraction of the total time without incurring the risk that a new user will be denied service or delayed. Also, it is evident that for a group of given size, as the efficiency of use approaches 100 per cent, the probability of exclusion also approaches 100 per cent, and the time of delay — if there is a waiting line — becomes indefinitely long. This last result is one of those that appears in an elegant body of theoretical material applicable to the loading of ore freighters, the selling of tickets to "My Fair Lady," or the stacking of planes over Newark Airport. It has been applied for some time to the telephone business and is called "queueing theory."

Limitations now important in the practical telephone business and thoroughly studied because of their importance, will be circumvented in a different manner as research and development now in progress at Bell Telephone Laboratories move forward. In the new approach we are emulating Alexander the Great and cutting the Gordian knot. Our sword is electronics, particularly solid-state electronics. What electronics offers is simple, but powerful — speed. In comparison with early telephone tools, electronic units provide lots of speed, and more each year.

Frequency multiplexing is the well established method of capitalizing on electronic speeds in the telephone business. But now the idea of time sharing implemented with electronic speeds gives promise of overtaking, and possibly in the longer run, of exceeding in economic importance the idea of frequency division. In the telephone industry, the first major effort to capitalize on this combination is electronic switching.

The principles of electronic switching have been discussed enough so that a substantial account of them in this article would be redundant (see Proceedings of the I.R.E., *October*, 1953, p. 1341; BELL SYSTEM TECHNICAL JOURNAL, *September*, 1956, p. 991 and RECORD, *September* and *October*, 1958). It is perhaps sufficient to remember that in even a very large and busy installation, say one with 50,000 telephone lines, and with each line making an average of two calls per hour, the number of new calls per second is only around thirty. By contrast, the number of operations per second obtainable in conventional digital electronic control equipment is easily 100,000. The key idea behind ESS (Electronic Switching Systems) lies in the idea of time sharing a single high-speed common digital control to perform all of the tasks associated with giving central office service to a large number of customers. The economy arises because multiplicity of control units is not needed. Time sharing in which a large number of users share in time sequence a common high-speed and highly accessible facility may reach its highest development in digital electronic control for telephone switchin[illegible] in ESS or its successors.

Time Division

"Even while we speak, envious time has sped."
— HORACE.

Consider a simple communication link in which a transmitter and receiver are connected over a wire circuit (*see upper part of drawing on next page*). If a switch is opened during a conversation and not closed until after five crucial words are spoken, it is obvious that the sense of the conversation will be drastically impaired. But now suppose that the switch is opened and closed at a faster rate. Suppose further that we are dealing with a typical channel bandwidth of 4,000 cycles. If the switch is opened and closed at a frequency somewhere in this range, say 1,000 times per second, a loud tone will be generated at this interrupting frequency. How-

ever, as the frequency of interruption is increased out of the audible range — up to 100 kc, for example — it is clear that the interrupting tone cannot be heard, and that the desired message might come through faithfully, though diminished in amplitude.

Since this is possible, it is also possible for several pairs of talkers to share a single pair of wires on a time-division basis. As shown in the bottom part of the first drawing, we might have three transmitters connected to three receivers over a single circuit. Instead of a simple switch, we now have synchronized electronic gates. As a rotating arm sweeps over the contact for transmitter 1, the corresponding arm is in the same position for receiver 1, and so on. The pulses representing each individual channel thus take turns entering the common channel.

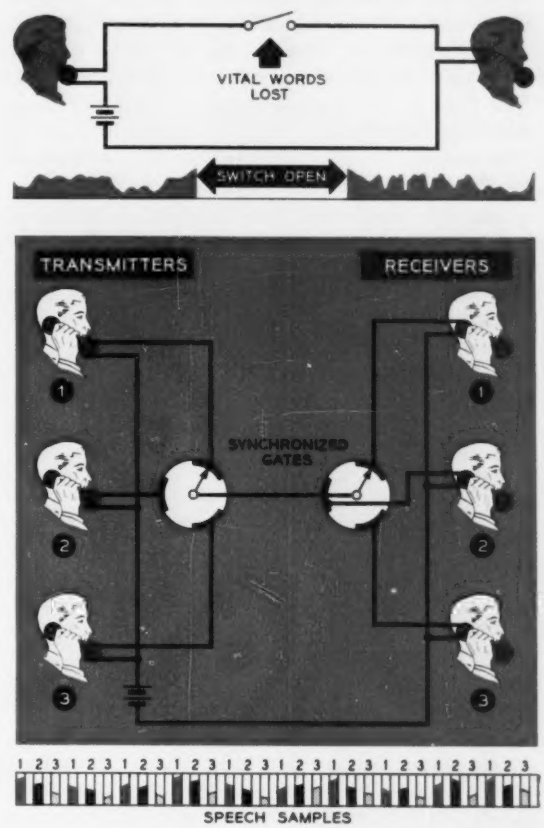
The sampling theorem of communication theory states this result in a quantitative way as follows: "The signal in a frequency band from 0 to f cycles per second can be conveyed by a sequence of regular samples which occur at a rate of 2f per second or more." Thus, in the drawing, the three talkers at the left can be heard without ambiguity and interference by the three listeners at the right if the switches are commutated at 2 times 4,000 or 8,000 cycles per second. Actually, of course, the transmitted spectrum for one channel would include not only the desired band, but would also include harmonics and their sideband frequencies. For this reason, the listeners in the drawing would have to be protected with low-pass filters to cut out all energy above 4,000 cycles.

This principle of time division has been used in radio communication systems. In just this form, however, it is unfortunately not a satisfactory multiplexing system for existing telephone cable. This is because consecutive pulses get bounced around and otherwise distorted in the cable so that they overlap. Such overlap means crosstalk. However, something can be done about that too — and that is to use regenerative PCM (Proceedings of the I.R.E., *November*, 1948, p. 1324).

Regenerative PCM — pulse code modulation — is based on a combination of two ideas: encoding and regeneration. *Encoding* is the process of reducing a continuous signal to a digital, usually to a binary, signal. The signal is first sampled as to time division. Then the sample is approximated by the nearest one of a number of definite "quantized" or discrete values. A voice signal is first sampled at a rate of 8,000 times per second, then each sample is represented as the nearest one of 128 possible levels. Since 128 is equal to 2^7, the sample can then be represented by a sequence of 7 binary pulses and the voice signal by 56,000 (8,000 x 7) binary pulses or "bits" per second.

This process is represented in the second drawing (*see next page*). Here, to simplify the representation, we have restricted the number of levels to 8 (0-7, or 2^3). The information signal is shown sampled five times, and the closest discrete values of the five amplitudes are, in sequence, 1, 4, 2, 3, and 6. On the binary scale, these values become 0,0,1 — 1,0,0 — 0,1,0 — 0,1,1 — 1,1,0. These are the code groups sent over the line, as shown by the encoded pulses drawn below the graph.

The method of sampling has been explained above in a general way — but what about the method of encoding? That is, for example, how do we get from a discrete level of 6 to its coded



In upper drawing, a switch interrupts voice channel slowly; vital words may be lost. In lower drawing, synchronized gates sample speech from telephones and deliver samples to receivers; with high-speed sampling, speech is undistorted.

form 1,1,0? One of two methods is generally used. In the first, an electronic circuit is employed which plays a game of seven (rather than twenty) questions. In one simple form of this game the sample is compared with a standard level somewhere in the middle of a possible range of 2^7 or 128. If it is greater than its standard level, a pulse is sent and the standard is subtracted from the sample. If not, no pulse is sent and no subtraction is performed. The remainder is then multiplied by two, and compared again with the standard level; and the process is repeated. The result is one type of binary code in which each code group has seven positions. One group — say 0,1,1,0,0,0,1 — states that the sample measured at 49 out of the 128 possible discrete levels.

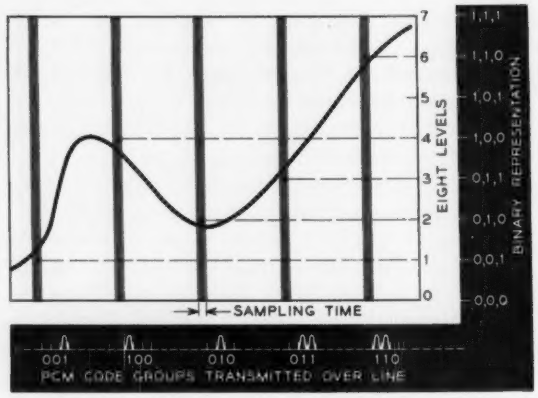
This is an acceptable encoding process except that weak parts of a signal are not represented with sufficient fidelity, because a small change in a weak signal is significant, whereas a small change in a strong signal can usually be ignored. This difficulty is overcome by placing a pair of nonlinear circuits at the two ends of a PCM link. The first of these expands lower amplitude signals and compresses higher amplitude signals. The second does the reverse. This is known as "instantaneous companding."

Another technique for encoding is to use a special cathode ray tube in which a fan beam is moved in the Y direction by the amplitude of the sample. This beam passes through a code plate into which apertures are cut in the X direction at each Y level to deliver the appropriate code (BELL SYSTEM TECHNICAL JOURNAL, *January*, 1948, p. 44; RECORD, *October*, 1948). This technique is particularly useful where the encoding must be at high speeds, as in television.

Decoding a PCM signal is a straightforward procedure in which the successive pulses are switched into different channels, weighted and combined.

Regeneration is an operation which vastly increases the possibilities of PCM. When a signal has been reduced to a chain of binary pulses, the only thing significant about each pulse is whether it is there or not. It is amplified, retimed, and reshaped into standard form, and sent again on its way.

Note how a regenerative repeater system may differ from a system of the more familiar analog type, particularly where the number of repeaters is very large. In the ordinary repeater chain, used in coaxial cable or microwave radio, distortion introduced by any amplifier, and interference anywhere along the path, appears in the final output. The inevitable consequence of this is that tight requirements must be placed on all parts of the system. Amplifiers must be highly linear. Without heavy feedback, they would be entirely impractical. Noise margins in each link must be much greater than the over-all requirement.



Smooth (analog) signal is sampled, and values of amplitude are recorded as closest discrete (digital) value on scale 0 to 7. Binary values are shown at the right and in their PCM form at bottom.

In contrast, the situation in PCM is relaxed. If the signal-to-noise ratio in every link is good enough so that an error in pulse recognition is very unlikely, the system will work properly. To be sure, an error made in any one repeater will appear in the output, but since the error rate in principle diminishes steeply as the signal-to-noise increases, this should cause no insurmountable difficulty. One should be able to use a large number of repeaters.

A regenerative repeater can be made by combining a clock, a gate, a slicer, and a pulser. The clock is used to activate the gate, which samples the incoming signal at the instant of time when its amplitude should be greatest. The result of this sampling determines whether or not a pulse will be sent at the next standard outgoing interval of time. The phasing of the clock can be derived from the incoming signal by averaging, or in a PCM system, where there are many channels, from a signal in an independent channel (*see drawing on next page*).

Because each repeater reconstitutes the signal, the signal can be attenuated, distorted, and considerably interfered with in each link. The transmission medium can be cheaper than that required for analog signals. For example, it is feasible to send voice multiplex or television over cable pairs for long distances by this method. Of course many repeaters must be in-

serted, but as the cost of electronic, and particularly solid state equipment becomes lower, this approach should become more and more attractive.

As briefly outlined here, this theory is obviously of great interest to anyone concerned with communications. But what does it mean in terms of systems that might become available in the future? At Bell Laboratories, a 24 voice channel PCM system is presently in the preliminary stage of development (*Fortune* Magazine, *December*, 1958; RECORD, *June*, 1958). In addition, research on PCM television transmission has been underway for some time, following the pioneering work of W. M. Goodall of the Holmdel Laboratory, who showed that this could be done (RECORD, *May*, 1951). Recent research work is aimed at transmitting a full black-and-white or color television signal over seven standard 22-gauge conductor pairs in a cable. It turns out that this is possible in the laboratory. With 19-gauge cable and a somewhat better repeater, the spacing could be extended to 6,000 feet — the distance between loading coils in some present voice-frequency lines. In the field of microwave radio, PCM might allow better use of frequency space because of its relative invulnerability to interference.

Waveguide of circular cross-section, operating with the circular electric mode, has the fascinating property that its attenuation per mile becomes less as frequency becomes higher. For a number of years, therefore, a Laboratories research effort has been directed at a possible high-capacity system using the circular guide. A problem, however, is that energy can, and does, leak back and forth between the circular electric mode and the 100 or more unwanted modes that are also possible in the guide. This effect causes interference in the transmission path, which can perhaps best be overcome by using PCM. In such a broadband medium, it is economically desirable to use many pulses per second. Techniques for handling as many as 500 million pulses per second have been demonstrated, and there seems to be no law of nature to keep the number from going considerably higher.

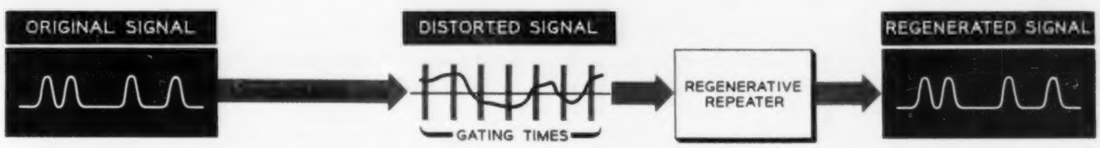
Since these possible applications range from the relatively low capacity of the 24-channel system to the fabulous information-carrying capability of the waveguide, one naturally wonders whether we will some day have a "super" transmission plan based largely on PCM techniques. Fairly small numbers of PCM channels might be assembled into larger and larger groups in coaxial cables, and finally combined for transmission over "backbone" waveguide routes at information rates perhaps as high as a trillion bits per second. This large capacity would include thousands of telephone conversations, many television programs, and hundreds of additional channels for data, teletypewriter, and other special services.

Time-Division Switching

"I shall arrive, what time, what circuit first, I ask not." — BROWNING.

The idea of time sharing is not limited to transmission. As mentioned earlier, it is also potentially applicable to control equipment in electronic switching systems. But time sharing can do more than this for switching — it can also save a very large percentage of the switches themselves.

The next drawing (*see the next page*) shows the type of thinking behind these potential savings. In the upper part of the drawing is a conventional "space division" switch for connecting ten lines to four trunks. This type of switch requires 10 x 4 or 40 "crosspoints" so that a connection can be established between any line and any trunk. The lower part of the drawing, by contrast, shows how the same function might be accomplished by "time-division" switching. Instead of 40 crosspoints, there is here only one gate for each line, plus one for each trunk — or 14 in all. As discussed earlier, a satisfactory connection can be made by connecting a line to a trunk 8,000 times a second. A "frame time" of 1/8,000 second (125 microseconds) can serve all four trunks. Less than one quarter of the frame time, therefore, is devoted to a connection from trunk C, say, and line 7. The remainder of this time is thus free for three other conversations over trunks A, B and D without



The principle of regeneration: original signal (left) may suffer great distortion (center), but so long as repeater detects presence or absence of pulse, code is perfectly reproduced (right).

interference. All four conversations are in time division on a single conductor.

Additional equipment is required, of course, to open and close the gates in the right time slots. This is the "memory" indicated in the drawing; it records "who" is talking to "whom" in "what" time slot. Also included is a mechanism for activating gates in accordance with the commands of this memory at the sampling rate of 8,000 samples per second. Even when this equipment is added to the 14 gates, it is found that in a sizable switching network based on this principle, the combined number of gates and memory elements should be fewer than the number of crosspoints — perhaps only one-half or one-third as many. An electronic PBX based on this principle is now in the preliminary development stage at the Laboratories, and larger systems are possible.

Integrated Time-Division Communication

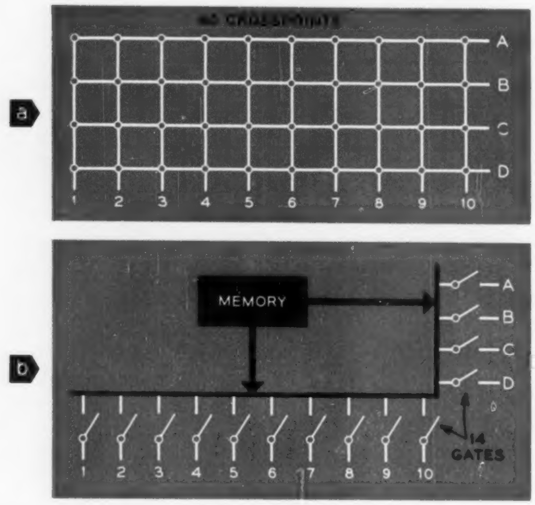
"Time is money." — MONTAIGNE.

The potential savings we have been discussing are in numbers of devices and numbers of conductors, but it would cost something to convert electrical voice signals from their ordinary form into time-division form. Once in time-division, therefore, why not leave them there as long as possible and derive both transmission and switching advantages in one integrated arrangement? Researchers at the Laboratories have been exploring a system concept which could make this possible — ESSEX, or experimental solid-state exchange. In ESSEX, the customary separation of the transmission and switching functions is abandoned.

To visualize this idea, consider about a hundred or more customers' telephones in a given geographical area. The lines would be brought to a "concentrator" near the telephones, and at this concentrator, lines which are talking are time multiplexed and PCM-ed — that is, the speech signals are sampled at high speed; the samples are "interleaved" in their assigned time slots; and the samples are reduced finally to their PCM codes. In PCM form, then, the signals are sent over a single pair of wires to the central office. Here, they are switched by time division and then routed to the concentrators corresponding to the terminating customers. At these concentrators, they are decoded and de-multiplexed, and the reconstituted speech signals are sent on to the listening customers. Each concentrator is connected to the central office by just three pairs of wires: one pair for sending, one for receiving, and one for control. Central offices can also be connected by PCM trunks without additional multiplexing.

Aside from the advantages already mentioned, this idea has another attractive feature. The calling and called telephones may be across the street or across the continent, but so long as the signals are in PCM form, transmission can be of standard level and quality.

Telephone systems philosophers can now visualize time sharing as a common principle underlying integrated transmission-switching systems and network communication systems including wire pairs, coaxial cable, microwave radio and circular waveguide. Of course this may never happen. There are many problems to be solved, of which the greatest is compatibility — how to move from *now to then*? On the other hand, there are many who feel that the idea of time sharing is so powerfully embodied by modern electronics that it is just a question of time, ingenuity and hard work.



A space-division switch (top) needs 40 devices ("crosspoints") to connect 10 lines to 4 trunks. However, a time-division switch (bottom) needs only 14 gates, plus a small percentage of memory and access devices to perform same function.

A contributor to the success of the underseas telephone cables is the science of plastics. These materials play an important part in the present cable structure — that of the insulation. Thus the plastic must meet strict requirements initially and also be able to withstand the ravages of underseas environment.

J. B. Howard

Plastics for Underseas Cables

September 25, 1956, marked an important milestone in communications history. On that day, the first telephone cable linking North America with the British Isles was put into service. This joint venture by A.T.&T., the British Post Office and the Canadian Overseas Telecommunication Corporation realized a dream of many years. Previously, there had been only radio-telephone service over this route and the new cable furnished, for the first time, overseas circuits with the quality and reliability of overland lines.

Plastics play an important role in this cable — a role cable engineers believe may be even more important in future underseas transmission lines. These materials may also be applied to the critical components of the necessary amplifiers. And quite possibly, they will be used as the outer protective covering in place of the "armor" of conventional cable.

In submarine cables, plastics are used for both of these purposes — insulation and protection. This article will be primarily concerned with the problems involved in selecting plastics for these applications. So it may be well first to consider briefly the physical structure of a typical underseas cable.

The electrical member of the present deepwater design is a coaxial cable consisting of a copper wire 0.1318 inch in diameter enveloped in a helix of three copper "surround" tapes 0.0145-inch thick. These tapes, evidence of the highly conservative nature of submarine cable art, are for continuity of the circuit in the event of a break in the solid center wire.

The dielectric surrounding this composite central conductor is a 0.620-inch outer-diameter layer of polyethylene (of high molecular weight) compounded with five per cent, by weight, of butyl rubber plus a suitable anti-oxidant. The electrical path is completed by a helix of six copper "return" tapes 0.016-inch thick spiralled around the dielectric.

Surrounding the electrical member are the protective and strengthening layers, most of which

have remained substantially unchanged since their prototypes were introduced to submarine cable design in the middle of the last century. First is the teredo tape, an overlapped helix of 0.003-inch copper tape intended to prevent damage to the insulation by marine borers. Next is a cotton binder tape coated with butyl rubber, then a single layer of cutched jute to serve as bedding for the high-tensile steel armor wires. Despite their names, the primary function of these wires is strength — for handling, laying, and possible recovery of the cable. Two layers of coal tar-impregnated jute over the armor wires complete the cable structure.

Since there is little to impede ready access of seawater to the outer surface of the polyethylene dielectric, this structure comprises a "wet core" cable. It is, in fact, kept in water continuously after the final stages of manufacture, except for brief periods while being transferred into and out of the holding tanks aboard the cable-laying ship.

Once installed in the depths of the ocean, the cable is not readily accessible, and repairs are both difficult and expensive. Cable designers, therefore, specify far more extensive precautions in selecting and handling the various component materials than they would for land cable.

Special Characteristics

Much of this precaution centers around attempts to keep contaminants out of and away from the polyethylene insulation. For example, the lubricants required in drawing and rolling the copper tapes, and those used to prepare the jute, are carefully evaluated for possible effects on polyethylene.

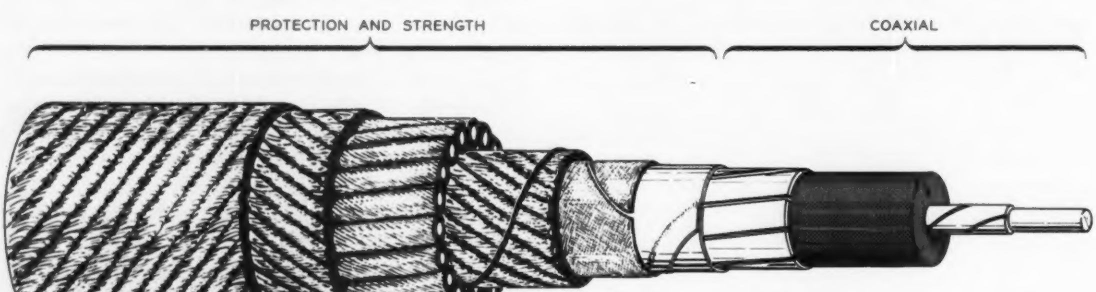
In the case of the insulating compound itself, such properties as adequate tensile strength and resistance to low temperatures are possessed by any sound conventional polyethylene and they demand no unusual consideration. Our attention then, will center around six special characteristics considered essential for dependable ocean cable. These are: uniform dielectric constant, a low dissipation factor, high oxidative stability, low contamination level, good environmental crack resistance, and uniform melt index.

Capacitance Control

Transmission characteristics of a telephone cable depend, of course, on its capacitance, and when the dimensions of the structure are held constant, capacitance is proportional to the dielectric constant of the insulating material. In the manufacture of ocean cable, an automatic device controls the extruding machine by continuously monitoring both the diameter and capacitance of the extruded cable core. Moreover, this device corrects for deviations through a feedback system.

Mechanical considerations permit no large excursions in the diameter of the extruded core to compensate for variations in the dielectric constant of the insulation. Therefore, close control of cable capacitance in practical terms means close control of the dielectric constant — so close as to require a special test procedure. As a result, Laboratories research workers have devised a test cell employing a benzene displacement technique. This determines both dielectric constant and dissipation factor of low-loss plastic to an accuracy not previously possible.

In essence, the method involves measuring the capacitance of a fixed-plate capacitor immersed at a precisely known temperature in a gold-plated cell full of pure dry benzene. Most of the benzene between the plates of the capacitor is then displaced with sheets of polyethylene compound, and the change in capacitance of the system is precisely determined. A particular ad-



Construction of deepwater cable used in transatlantic system. Note great care taken to avoid disrupted service — for example, three copper "surround" tapes complementing the center wire.

J. B. Howard, left, and K. G. Coutlee discuss the attributes of the benzene displacement technique. In this cell, a fixed-plate capacitor is immersed in pure dry benzene. Sheets of polyethylene compound displace most of the benzene and a precision bridge measures the change in capacitance.

vantage of this displacement technique is that the test sheets need not be as smooth or of as carefully controlled and measured thickness as for more conventional procedures.

The need for a low dissipation factor — a maximum of 0.0005 is permitted for present designs — can be filled by any clean unpigmented polyethylene. Cable engineers contemplate control to much closer limits for future cables that will carry broader-band signals. The frequency chosen for this test should preferably lie within the operating frequency band of the cable, particularly if this will include the lower frequencies. One reason for this is that the presence of certain types of impurity may be quite obvious in the low kilocycle range but may escape detection in tests made at either 50 or 100 mc.

Stability Test

A stability requirement against oxidation — the third problem — essentially verifies the concentration and quality of the antioxidant in the insulation compound. This test, developed at the Laboratories, has been part of polyethylene specifications for telephone and military cables for many years. It involves subjecting the material to a temperature of 160 degrees C for three hours under specified conditions, after which the original dielectric limits must again be met. An unstabilized or inadequately stabilized compound will not meet this requirement. Since the test imposes conditions substantially more rigorous than those existing in most extruders, materials passing this requirement will be thermally stable in normal processing.

Requirement number four — an extremely low level of contamination — is also critically important to submarine cable engineers. Bits of foreign matter in the insulation, even quite small ones, threaten the life of cable subjected to high-voltage stress. In principle, any included matter whose dielectric constant or conductivity differs greatly from that of the surrounding matrix could lead to premature electrical breakdown. The potentials to ground now used in repeatered submarine telephone cable are moderately high — over 2000 volts dc. While these voltages are below the normal breakdown level of polyethylene, they are high enough to cause concern, when the long-service life expectations are considered. This is particularly true if there is appreciable contamination present.

The level of contamination in the best commercial insulating compounds today is already

so low as to present problems in specification and inspection control. But it is still not low enough to satisfy the cable engineer. His problem is like that of finding the traditional needle in a haystack. Consider that a single malignant inclusion could incapacitate the entire 4000-mile transatlantic cable system, then imagine finding that inclusion in over two and two-thirds million pounds of insulating compound!

An obvious approach, of course is, to equip the insulating extruder with an effective filter or strainer, and this has been done. There are, however, very real limits to the amount of added impedance of this nature which can be tolerated by the extrusion equipment. For this reason, chemists also want to control the cleanliness of the incoming compound to maintain the desired level of quality.

This control is possible through a careful scrutiny, over a light box, of representative samples of compound in the form of a thin sheet. With this method, contaminating is controlled to a level that compares favorably with that of many drugs.

Environmental stress-cracking of polyethylene — the fifth major concern — results from the action of certain agents, usually surface active in nature, on poly-axially stressed polyethylene. There is as yet no evidence that sea water, ocean-bottom sediment or any by-product of marine biological activity contain materials harmful to polyethylene. But the characteristic conservatism of submarine cable engineers demands positive assurances against such contamination.

Stress Control

The addition of butyl rubber to the high molecular weight polyethylene of the insulating compound is intended as an added safeguard against such occurrences. These two materials apparently are not truly compatible, and when the extruded compound cools, the butyl rubber presumably separates into submicroscopic pockets. These little "shock absorbers" tend to equalize and dissipate externally applied stresses, as when the cable is flexed or bent. Thus stress concentrations cannot build up to a level at which environmental cracking could come into play.

The test for adequate resistance to environmental cracking is extremely severe. After preconditioning in an unstrained condition for 7 days at 70 degrees C, the test specimens are nicked, bent, and immersed in a concentrated cracking agent — no failures are permitted in the specimens. It is of interest that while many standard polyethylenes fail in a matter of minutes in this test, the polyethylene compound now in use for underseas cable has never failed.

The sixth vital characteristic — melt index — gives a measure of practical control over the range of molecular weight of the insulating compound. In association with melt index, the "recovery" is also a rough indication of processability, since for compounds with similar recovery values, those of higher melt indices extrude more easily. Melt index recovery places an upper limit on the amount of elastic memory or "nerve" on the raw material.

This characteristic can be modified by the extruding operation, and it can vary appreciably with the nature of the equipment and the process used. Material with low melt index recovery is desirable because it minimizes retention of the "shock" of the extrusion process by the "elastic memory" of the material. For absolute dimensional stability cable engineers would like to have the extruded insulation devoid of internal strains stored by this elastic memory. These strains could slowly relax over very long periods of time with resultant changes in vital core dimensions. Such changes, however small, would represent changes in capacitance, and hence in transmission loss with time. A cable system has very little tolerance for such changes.

The application of plastics technology to today's ocean telephone cable is limited largely to the primary electrical insulation of the co-axial. But some of the new, harder polyethylenes suggest themselves as outer coverings potentially more resistant to abrasion and cuts than the natural fibers in present use. Some of these new materials are worth noting.

As an example, chemists have discovered olefin polymers which are harder, denser and more crystalline than the polyethylene with which we are familiar. Products from different sources, or produced by process variations, may exhibit slightly different properties, but they also appear to have certain characteristics in common. In all these polymers, abrasion resistance usually varies with density.

Abrasion testing is a complex art, and test results have little meaning except in association with the method by which they were obtained. Resistance to the action of fine sand, for example, would seem to call for one type of material, resistance to sharp coral quite evidently for another. If the submarine cable engineer can specify the type of abrading surface against which protection is needed, then the chemist can make an intelligent selection of materials.

Many of these newer olefin polymers display

Author examines a wire coated with an unsatisfactory high-density hydrocarbon polymer that has been wrapped around itself. Exposure to elevated temperatures has embrittled the insulation so that it cracks at every convolution.

a characteristic unfamiliar in standard polyethylene — "thermal embrittlement," or "thermal stress-cracking." Immediately after extrusion, a wire insulated with these polymers can be wrapped around itself without damage. But after a few hours in air at 100 degrees C, or a few days in air at 70 degrees C, it may become so brittle that it cracks open on bending. The same thing may occur after the wrapped wire is stored for several months at room temperature. Generally, this effect is reversible when the sample is re-melted, so a physical, rather than a chemical change is probably responsible.

Certain of these same materials display another characteristic quite possibly related to thermal stress cracking. In Germany there have been failures of cold water pipe made from some of them. These failures were reported as apparently brought about by a creep mechanism (RECORD, *June*, 1957). But the brittle, rather than ductile nature of these failures resembles both environmental and thermal stress-crack failures.

Water, not normally considered active as an environmental cracking agent can alarmingly aggravate an effect in certain of the higher density olefin polymers. This effect is closely akin to thermal stress-cracking. At the Laboratories, racks of bent specimens, prepared from such a polymer in the manner used for the environmental crack test, have developed cracks within a week's time when placed in a 70°C dry air oven. When immersed in distilled water at the same temperature they shatter within a few hours. Fortunately, both these short-comings can be overcome by appropriately "tailoring" the polymer molecules. Furthermore, crack resistant, high density poly-olefins of superior abrasive resistance are becoming available.

Less heralded than the more rigid olefin polymers, but of great possible importance to submarine cable, are new super-crack-resistant standard, or low-density, polyethylenes. Some of these appear to have crack resistance at least equal to the present butyl-rubber modified compound. Such polymers are primarily of interest for use as the dielectric in ocean telephone cable, but could serve also for sheathing in designs which do not demand maximum abrasion resistance.

Chemists know little about the behavior of any of these materials on actual long-time exposure in the marine environment. Possible attack might come from at least three sources, not including human mischief. First are the living animals — the shipworms, and the burrowing clams — which could inflict direct mechanical damage. Second are the fungi, the bacteria, and other organisms which could consume the material for their own sustenance. Last, there is the possibility of chemical damage from excretions and other by-products from either of the former groups.

To further studies on cable life, Bell Laboratories chemists and biologists are making exposure tests with the William F. Clapp Laboratories of Duxbury, Massachusetts, at two locations along the southeastern coast of the United States (RECORD, *August*, 1957). They are also making laboratory tests, using marine microorganisms, to study the ability of varying organic materials to support bacterial life. Such tests are the basis for selecting polymers most likely to resist environmental factors at ocean bottom.

Today, one ocean telephone cable system links North America with Europe. By the end of this year there will be another. Within our lifetime there will undoubtedly be additional facilities extending to other continents, each incorporating the latest advances of science and technology. In this attack on the problems posed by placing a transmission medium in a potentially hazardous environment, the cable engineer, the transmission engineer, the materials chemist, and the marine biologist are working together to provide reliable and economical avenues for the exchange of information between different lands.

Signaling, an essential part of good telephone service, takes various forms in establishing, releasing and monitoring calls that must go over many trunks and through many different switching systems. Because signaling is so important, Bell Laboratories engineers have developed a versatile new system that can be used with almost all Bell System trunks and switching schemes.

C. A. Dahlbom

A TRANSISTORIZED SIGNALING SYSTEM:

Engineering Aspects

In telephone transmission, the main objective is a clear, reliable voice channel between the customer's telephone and the telephone he is calling. In addition to voice transmission, however, it is necessary to transmit various signals that direct and supervise the progress of a call. Pulses representing the digits of the called number, for example, direct the call. And change-in-status information—the customer's answer with an "off-hook" signal or his disconnect with an "on-hook" signal—together with various information signals, supervise calls. Signaling is thus an important part of good telephone service, and engineers must always give it careful consideration when they are planning improvements in telephone service or equipment.

The many methods of signaling over telephone lines can be grouped broadly into ac techniques and dc techniques. Signaling is generally further distinguished as "in-band" or "out-of-band." In the dc techniques, the presence or absence of current signifies a signaling state, while pulses of direct current—for example, five pulses representing the digit 5—are sent over the line for control information.

With ac signaling, the presence or absence of a tone signifies a signaling state, while pulses of a certain frequency or combination of frequencies may be transmitted as control information. With ac signaling, it is possible to send signals either within the same frequency band used for voice conversations ("in-band"), or in a separate, smaller frequency band allotted exclusively for signaling ("out-of-band").

Direct-current signaling is the oldest, and in many ways the simplest, method. But for the modern telephone plant, it has two disadvantages. First, dc signals are limited to fairly short distances, which means they are generally suitable for transmission between local exchanges but not for long-distance use. Second, this method requires a dc path, which is often not available, especially over carrier systems.

Because of these disadvantages, systems en-

gineers at Bell Laboratories realized early in the planning stages for direct-distance dialing (DDD) that new ac signaling methods would be needed to supplement existing dc methods. Also, a continuing effort to apply carrier methods to local transmission facilities gave additional emphasis to the development of new ac signaling techniques. Both DDD and local-carrier plans favored the use of an in-band system, since this arrangement conserves frequency space and is more adaptable to a variety of transmission systems.

The earliest ac, in-band signaling system for dial trunks was developed at the Laboratories shortly after World War II (RECORD, *July*, 1951). This single-frequency (SF) signaling system uses a 1600-cycle tone. The 1600-cycle frequency was chosen to permit the SF system to operate over all types of voice and carrier channels then in use. More recently, a 2600-cycle SF system was developed for broadband voice circuits (RECORD, *February*, 1954). This system, used in-band, serves most of the Bell System's long-distance transmission network.

A 3700-cycle SF arrangement, developed at about the same time, is used out-of-band for the N, O, and ON carrier systems. In this arrangement, the signaling frequency is used in a frequency "slot" above, but adjacent to, the voice band. Recently, these carrier systems have been made available without the built-in, out-of-band signaling equipment so that they can be used economically with in-band signaling arrangements.

Design Considerations

Since several SF signaling systems were available, and since the basic techniques were well established, studies for the new ac signaling arrangements for exchange trunks focused principally on the problem of reducing costs while improving service. This approach centered about the application of "new art" techniques—the use of solid-state devices such as transistors and semi-conductor diodes, along with miniaturized components and printed wiring. Such techniques promised potential savings in the initial cost of the signaling units, and they also indicated the possibility of other attractive features, including smaller size, lower power consumption, and improved testing and maintenance possibilities.

At this point in the planning of the new signaling units for exchange applications, an interesting question arose: why not apply to toll signaling the same techniques that promised economies in signaling over exchange trunks? The project was therefore broadened to include the requirements of both exchange and long-

The author points out one of the transistors on new in-band signaling unit to W. R. Cano, center, and N. A. Newell. All available options are identical in size and much alike in appearance.

distance transmission, and a "building-block" equipment design was conceived to derive the most from the savings inherent in large-scale production. In a few words, then, the goal was to design a single-frequency, in-band signaling system, using new-art techniques and the building-block principle. And the new system was to be applicable to carrier trunks for both exchange and long-distances. Needless to say, a number of problems had to be solved before this plan became practicable.

One of the most important of these problems concerned the pulsing arrangements required by a signaling system designed to work with all types of switching systems. Pulsing is very important because it transmits vital routing information, the called number. It does this variously: by dial pulses, multifrequency pulses, revertive pulses, or panel-call-indicator (PCI) pulses.

In long-distance trunks, when dial pulsing is used, the pulses take the form of spurts of a single-frequency tone, equal in number to the value of the digit being transmitted. The increasingly popular alternative to dial pulsing is multi-frequency (MF) pulsing, in which each digit is represented by a single pulse composed of two frequencies. MF pulsing allows much higher pulsing speeds.

In exchange trunks, two other pulsing arrangements—revertive and PCI—are also quite commonly used to transmit the called number. Revertive pulsing is a relatively high-speed system

(almost three times faster than dial pulsing), originally used for signaling between telephone offices that use panel-type switching. Here, pulses are sent from the terminating to the originating office (hence the term "revertive") under control of start and stop signals from the originating office. The revertive system uses dc, with three current states — negative, positive, and zero. To transmit similar signals by ac, over either a voice-frequency or carrier channel, requires a signaling system capable of transmitting three conditions, unlike the binary, or two-state, capability of the usual SF signaling arrangements. This means that an additional frequency, or "dependency-on-time" discrimination is required to introduce the third signaling condition.

PCI pulsing, another relatively high-speed dc pulsing arrangement, was originally introduced for transmitting pulses between panel switching offices and equipment for displaying dialed numbers(call-indicator display) in manual telephone offices. Here, digits are represented by a four-interval code and are received and registered temporarily on relays. The digits of the dialed numbers are then displayed before the telephone operator on lamps.

The transmission of supervision and PCI signals over carrier systems requires five signaling states, however, and equipment that is this versatile is expensive. Also, the need for PCI pulsing will gradually decrease as manual offices are cut over to dial and as multifrequency pulsing is substituted in other applications. An ac signaling arrangement capable of handling PCI pulsing is therefore not presently planned.

Field Locations

Another important consideration in the design of signaling equipment is the ultimate location of the units. These field locations of course vary for different switching systems and switching applications. The signaling circuits for long-distance trunks, as the diagram on this page shows, are usually physically separated from the trunk circuits but are connected to them by two leads, historically designated "E" and "M." Signals from the trunk circuit to the signaling unit go over the "M" lead, while signals in the reverse direction from the signaling unit to the trunk go over the "E" lead.

The diagram shows a typical long-distance application of in-band signaling, arranged for E- and M-lead terminations. As with most long-distance facilities, this is a four-wire line—either voice frequency or carrier derived—with central-office switching equipment at both terminals. There are of course other applications and resultant combinations of equipment.

Actually, the various trunk terminations for long-distance and exchange transmission are so different that no single signaling arrangement will meet all conditions. But the basic functions

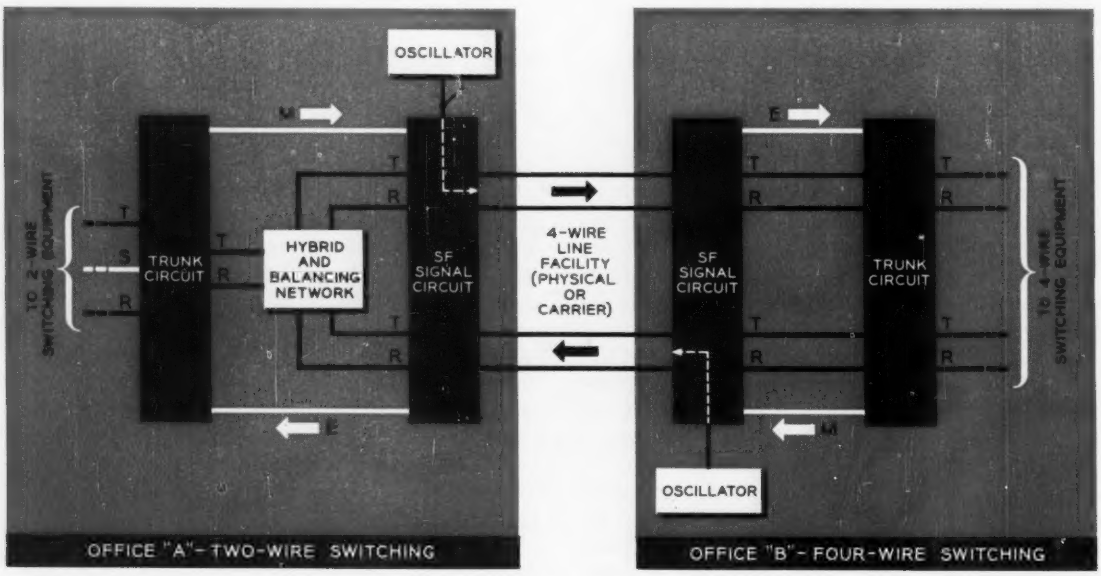


Diagram showing a typical arrangement of trunk and signaling circuits and how information is passed between them over "E" and "M" leads. The transmission circuits are of the four-wire type.

of the signaling system, except for revertive pulsing, are the same.

Present plans call for the development and manufacture of new transistorized SF signaling units with seven equipment options. These options will meet the signaling demands for most exchange and long-distance applications. Three units will be arranged for E- and M-lead signaling — one of these units, to be used for two-wire switching, will include a four-wire terminating set, and the other two units will be used for four-wire switching applications.

The remaining options are restricted to one-way operation, and all of these units include four-wire terminating sets. This group takes care of loop-signaling terminals, has two units for the originating and terminating applications where the dial or multifrequency types of pulsing are used, and also has two options for the originating and terminating applications where revertive pulsing is used.

Physically, all of the units have about the same appearance. A typical unit is shown on the right in the photograph at the top of page 255. These are plug-in units that can be readily inserted or removed from mountings that are arranged to hold up to 90 units on a single central-office frame. By contrast, only 30 units of the earlier electron-tube version can be mounted in the same space. The reduction in size and the compactness are made possible by the use of new-art components and the latest design and manufacturing methods.

Low Power Requirements

The new transistorized units use only one third to one half as much power as the earlier version, thus reducing heat dissipation. And more importantly, they require only one-48-volt power supply. New transistorized tone supplies, capable of handling as many as 90 circuits, have also been designed to go along with the new SF signaling units.

This newest advance in the important field of telephone signaling will make possible an increase in the use of carrier trunks, and ultimately the further growth of DDD in many areas. It will also help to standardize signaling arrangements throughout the Bell System. Through its versatility and economy, the new in-band signaling equipment will also help Operating Companies to realize substantial savings in both the first cost and annual charges for exchange and long-distance signaling.

Experimental Design: "Dial-in-Handset"

Mrs. Rose Calleo of Bell Laboratories demonstrates use of the new experimental handset. Dial near center of instrument protects against inadvertent operation and permits easy dialing.

In what could be an important "new look" in telephone designs, the dial has been placed between the transmitter and receiver in an experimental handset. Tentatively called the "dial-in-handset" telephone, the new unit was developed by the Apparatus Development Department at Bell Laboratories, in collaboration with industrial designer Henry Dreyfuss. New Jersey Bell is now installing 250 trial models in 172 residences and business establishments in New Brunswick, N. J. The purpose is to test customer reaction to appearance and operation.

For some types of installations, the new handset may offer added convenience in telephoning. It is intermediate in weight between the black and color handsets of the 500-type telephone set, and its outer shell has been carefully contoured to fit the user's hand. It also includes a light to illuminate the dial surface. The base for mounting the instrument can be placed flat on a table, as in the photograph, or it can be mounted on a wall or side of the desk.

Efficient filters underlie all carrier transmission. For P1, latest of the local carrier systems, Bell Laboratories engineers used the most modern components and techniques available to design filters that are efficient, compact, and easy to maintain and install in rural areas.

F. J. Hallenbeck and E. W. Holman

FILTERS FOR THE P1 CARRIER SYSTEM

Carrier transmission takes advantage of the fact that voice frequencies can be used to modulate a "carrier" frequency. Several different carrier frequencies thus modulated may be combined and transmitted simultaneously over a single pair of conductors. The carrier principle is used in both radio and television transmission and has been used in the Bell System on long-distance facilities for many years.

With the advent, some years ago, of the M carrier system, the advantages of carrier transmission have been adapted to connecting telephone customers to the central office. The newest "local" carrier arrangement is the P1 Carrier System (RECORD, *August*, 1956). This system is designed primarily for use in rural areas where individual customer lines may extend some distance from the central office. By dividing a single line into four carrier channels, this system can avoid the construction of additional, individual "physical voice" lines to connect rural customers to the central office.

To do this, however, the P1 system had to be carefully designed to make the cost of the equipment for the carrier channels and for all of the other necessary transmitting and receiving equipment competitive with the cost of the cable or open-wire lines which would otherwise be required. In this respect, one of the important elements in carrier systems is the filter arrangement at both the transmitting and receiving terminals. These filters, which make possible carrier-channel separation, "recognize" certain frequencies and either pass or block them.

Filters normally account for about one-quarter of the cost of a carrier terminal. This meant that many of the economic and technical decisions concerning the P1 system were based on the cost of the required filters. But cost was by no means the only design consideration. The field of use of a rural carrier system simultaneously imposes rather severe demands on the physical size and shape of the filter package.

First, the filters had to be small. In the P1 system, terminal equipment remote from the central office is almost always mounted on a telephone pole near the customer's premises. The filters therefore had to be comparable in size and weight with units that use transistors and other miniature components. The other requirement

that the general character of the system imposes on the design of the filters is ease of maintenance and installation. Even moderately complex electronic equipment can cause some maintenance problems when the work must be done in the local plant, which is generally not geared to the electronic practices of the toll plant. The same can be said for adding or removing channels from the system.

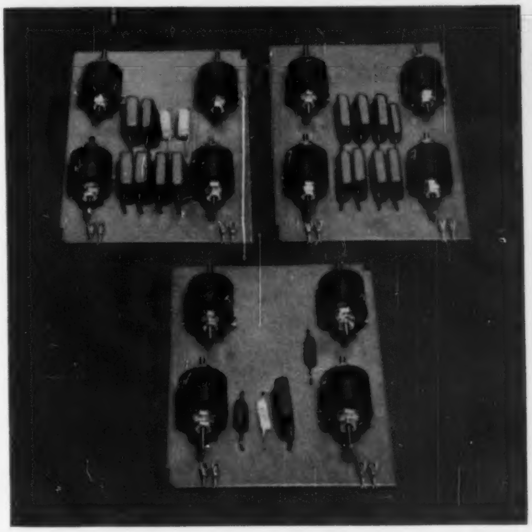
In a few words, then, the two most important problems that confronted the designers of the filters were low cost and the restrictions of a small, easily replaced package. Since many of the system considerations were based on the cost of the filters, let us first consider the system aspects of the cost problem.

Past experience in carrier technology showed that channel filters for systems using double-sideband transmission (transmission intelligence on both sides of the carrier frequency) are simpler than their counterparts in single-sideband systems (intelligence on one side only). This is particularly true in the transmitting units. Also, if the carrier spacing—the difference in frequency between channels—is wide, it is easier to provide filters of adequate performance. The first of these factors was used in the design of the N carrier system, where the double-sideband carrier channels are 8 kc apart (RECORD, *July*, 1952).

The P1 system takes advantage of both of these factors by using double-sideband transmission and by increasing the spacing between carrier-frequency bands to 12 kc. The final system plan calls for eight transmitting and eight receiving filters tuned to 12-kc intervals, with 12 kc the lowest frequency. Six additional filter combinations have also been designed so that the "staggered" channels, if required, can operate midway between the "normal" frequency channels (RECORD, *October*, 1956).

This system plan made it possible to use filters of relatively low cost. The next step was to exploit this economic potential. This was done in three ways: (1) low-cost components (consistent with reliability) were sought, (2) configurations were designed to use these components most efficiently, and (3) inexpensive packaging and testing methods for the filters were investigated.

In the choice of components, two approaches were available. The channel filters could be positioned in the frequency spectrum by using a combination of inductors and capacitors that have all values fixed within close limits, or alternatively, by using combinations of fixed devices with wide limits and adjustable devices. At the lower frequencies, the cost of close-limit, fixed components is reasonable, but this is not true at the upper channels. Near 100 kc, very expensive fixed components are required for precise filtering and for insurance against changes in value due to temperature and aging.



Terminal filter packages. Cylindrical ferrite inductors can be adjusted with screws in front and rear. Other components on board are capacitors.

The second alternative was used in the P1 carrier filters. Values of filter capacitance in the frequency region below 100 kc are well out of the range of values obtainable in variable capacitors of reasonable size. Consequently, capacitors made of molded mica and having wide tolerance limits are used wherever possible. At the lower frequencies, where capacitance values would require large and expensive mica units, foil-Mylar capacitors — recently developed at Bell Laboratories — are used. These are miniature, "pigtail" units which, even in quite large values, are comparable in cost to the wide-limit mica capacitors.

Variable Ferrite Inductor

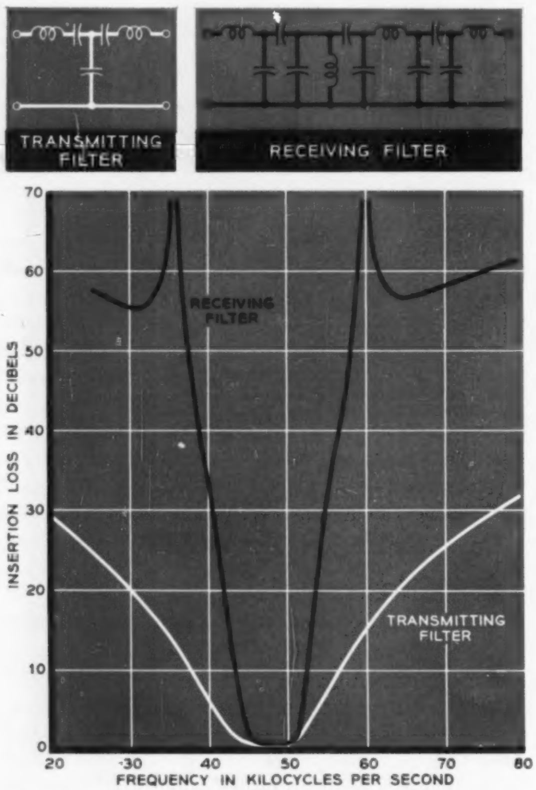
The variable component used along with either of these two wide-limit capacitors is a ferrite inductor developed especially for the P1 system These ferrite inductors are the cylindrical components shown in the accompanying photograph (*above*). A variable inductor of this same magnetic material is used in the channel filters for the O carrier system (RECORD, *April*, 1955; *May*, 1953). The new unit is smaller and less expensive than the older inductors.

Wide-limit capacitors are less expensive than

ferrite inductors so that the filter circuits (*see sketches on the drawing shown below*), were designed to take this factor into account. The curves in this drawing show loss-frequency characteristics of typical transmitting and receiving filters.

In solving the second important problem concerning the design of the filters — packaging — experience with previous carrier systems was of little value. In earlier systems, the size and shape of the filters were determined largely by attempts to make them into units that could be handled independently. Consequently, some filters were small enough to be mounted in an equipment subassembly or panel, and others were so large that they occupied the full width of a mounting frame.

By contrast, the P1 system employs new packaging techniques that have made the filters a much more intimate part of the equipment. In many of the equipment units, identical types of components are used, so that it is difficult for one not familiar with the equipment to distinguish between filters, oscillators or amplifiers. In fact, the filters are no longer identifiable by name because all of the units of the P1 system are coded simply as "networks."



Typical circuit arrangements used for terminal filters, along with curves of typical loss vs. frequency characteristics of both the transmitting and receiving filters for the P1 system.

Use of Printed Wiring

In addition to trying to minimize the size of the filters, the designers were faced with the problem of minimizing the cost of the filter chassis and the cost of assembling and wiring the units. Fortunately, one of the newest methods of packaging electronic apparatus — the printed-wiring board — fulfills both of these needs. Printed wiring makes possible a very compact assembly for the carrier terminal. Through the use of a wire grid and spring connectors, each "terminal-board" assembly can be fabricated as a plug-in unit. Also, because it is a self-wired chassis which permits automatic insertion of components and mass soldering, the printed-wiring construction potentially represents low manufacturing costs. Each of the terminal filters shown in the photograph on the previous page is mounted on a printed board, as are the "active" circuits such as amplifiers and oscillators.

To capitalize on this inexpensive fabrication process, low-cost adjusting and testing procedures have also been developed. In this method, a trace of the loss-frequency characteristic of the filter under final test is displayed on an oscilloscope with the trace of a reference filter. The variable inductors are then adjusted until the two traces are alike within prescribed limits. Thus the filters are adjusted and inspected at one test position. A laboratory set-up of this test method is shown in the photograph on the next page.

To this point we have been concerned primarily with terminal filters. Another important group of filters were developed for the repeaters of the P1 system. Here, both low- and high-pass filters are required to separate the direction of transmission, since the system operates over one pair of wires as the equivalent of a four-wire telephone circuit which uses two pairs, one for each direction. The repeaters also contain another set of networks which act as loss and phase equalizers, and the regulated repeaters of the system have "pilot pick-off" filters. All of these transmission networks are packaged in the same way.

Another special type of filter, although it does not appear at either the terminals or repeaters, represents an application of filters unique to the P1 system and also represents a unique packaging problem. In the P1 system, a voice circuit is normally transmitted from the central office along

with the carrier signals. This voice circuit is capable of serving eight party-line customers between the local central office and the first carrier terminal.

These special filters are placed on such lines and have two main purposes. First, they prevent drop wires — the connection between the customer's telephone and the main line — from absorbing excessive amounts of carrier power. Second, the filters are designed to prevent the carrier signal from affecting voice transmission to the customer's telephone. The obvious solution to both of these problems seemed to be a filter with an appropriately low-pass band, which would pass only the required voice frequencies.

In this case, however, the obvious solution is not the best practical solution. The problem becomes complicated by the fact that when the telephone is "on-hook," the drop wire is a capacitance that varies with the length of the wire. This varying capacitance has to be absorbed as part of the filter capacitance, which means that a provision would have to be made for "building out" various values of capacitance for each different length of drop wire. The incorporation of such a provision in a filter, plus the local-plant engineering required to determine the proper capacitance in each case, would have resulted in an arrangement that was both expensive and complicated.

By contrast, the solution to the problem of varying drop-wire capacitance in the P1 system is simple and inexpensive. The method still involves some local engineering, but this has also been simplified to the selection of one of four coded options — one for each of four ranges of drop lengths. The basis of the solution to the problem, then, is the selection of several inductance values, large enough to present sufficiently high impedance to carrier frequencies, but low enough to transmit voice frequencies without severe loss. The workman thus selects a value of inductance — matched to length, so to speak — and puts it in series with the drop wire. The capacitance of the drop wire, alone or in combination with a fixed-interval capacitance, sets the bridging resonance of this circuit in the safe region between the voice frequency and the lowest carrier frequency.

As with the terminal filters, however, satisfactory transmission was only half of the over-all problem in the design of these units. The question of cost and size still have to be considered. As many as eight of these networks might be used on a P1 line, so the amount of money invested in these filters could mount up fast. Also, the network is mounted on a pole where the customer's drop line meets the carrier line, so it must be designed to withstand all types of weather. This was done by using plastic encapsulation to make a simple yet rugged assembly.

F. J. Hallenbeck, standing, explains the procedure for adjusting and final inspection. Inductor is adjusted until characteristic on oscilloscope matches trace of standard reference filter.

Network Packaging

A styrene polyester is the casting material which encases the circuit. Standard carbon blocks are included in the network for protection against foreign potentials. The sturdy terminals required for "bridle-wire" connections are part of the standard carbon-block holders. Side slots in the casting permit it to be mounted in the wedge-shaped holder which is mounted on the pole with screws. A flexible rubber cover snapped over the face protects the entire assembly from rain.

The networks and filters for the P1 carrier represent a continuance of the pioneer efforts by Bell Laboratories in the use of modern design techniques to achieve economy and small size. The components and techniques developed for P1 carrier may influence the design of later systems requiring small, efficient electronic components and similar techniques in filter design.

Without a power supply, the transatlantic telephone cables would be little more than metallic ropes strung from Newfoundland to Scotland. The potential across each cable and its 51 repeaters is about 3800 volts, with four power supplies required for the complete two-cable system. Extreme reliability and constancy characterize this power system design.

R. E. D. Anderson

Power Supplies for the Clarenville-to-Oban Submarine Cables

The undersea repeaters in the transatlantic cables connecting Clarenville, Newfoundland, and Oban, Scotland, were designed to operate for years without maintenance. They could not, however, be designed to operate without power. Furthermore, the performance and lifetime of the system depend to a large degree on the precision, reliability and constancy of the power supply. As a result, most of the floor space in the cable terminal buildings is devoted to power equipment, even though the power delivered to each cable is only about 900 watts — less than that used by an average two-slice toaster.

The basic scheme for supplying power to the repeaters is shown in the first schematic. A direct current of 225 milliamperes is carried over the center conductor of the coaxial cable in a direction opposite to the voice transmission. In each repeater, there is a drop in potential of 54 volts across the heaters of the three electron tubes in series. Most of this voltage drop is used also as the source of plate and screen potential for the amplifier. Between repeaters, the average voltage drop in each section of the cable itself is about 20 volts. The total voltage across each cable, its 51 repeaters, and power-separation filters is more than 3800 volts. To keep the dielectric stress on the cable and the repeater components to a minimum, this voltage is divided equally between power supplies at each end. Four power supplies are thus required for the complete two-cable system.

Size and complexity of the power supplies result from several exacting system requirements. A continuous supply is of primary importance. A power failure, in addition to causing loss of service and revenue, would result in cooling and subsequent reheating of the repeaters, which could tend to reduce the life of the electron tubes. Excessive cable voltage or current would be more hazardous. The expense of replacing a submerged repeater justifies every preventive measure.

Close regulation of the cable current is a further requirement. Over-all transmission level

of the system is a function of the stability of the supply current, and because of this a requirement of 225 plus or minus 0.5 milliamperes under normal conditions was established, based on an allowable variation in transmission level of plus or minus 0.07 db. The regulators must compensate not only for ac input variations, but also for variations in earth potential between the two terminals. Geomagnetic storms following solar disturbances occasionally produce a considerable difference in earth potential, which aids the power supplies for one cable and opposes the supplies for the other cable. Power supply capacity was provided to accommodate "bucking" earth potentials of one thousand volts on either cable without loss of regulation.

A more detailed description of the power facilities falls naturally into three parts: (1) the ac plant designed to provide a reliable source of ac power; (2) the regulator bays, containing rectifiers to convert the reliable ac to dc, plus regulating circuits to provide the required stability of current; and (3) the common-control bay, containing the actual termination of the cable, with filtering, metering, alarm and protection circuits.

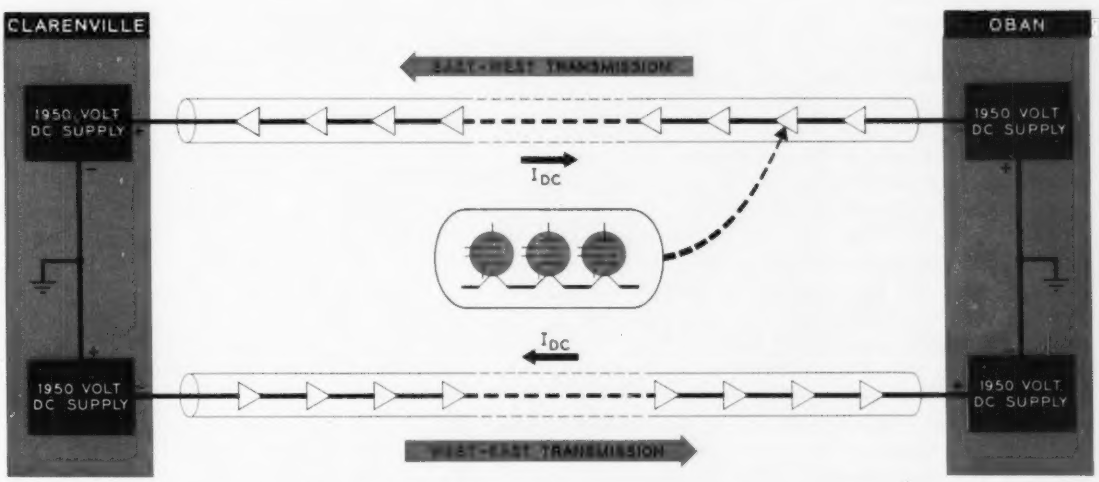
Commercial power serves as the prime power source, with diesel engine alternators acting as standbys. To provide continuity of ac power during transfers, a two-motor alternator arrangement is used. In this scheme, widely used for overland "L" carrier telephone systems, a 230-volt, single-phase alternator is applied as a buffer between the prime sources and the load. The alternator drive shaft is normally driven by a three-phase induction motor powered from the ac source. A second motor operated from a 130-volt battery is provided on the same shaft. This dc motor is energized automatically to keep the alternator rotor turning without interruption during ac failures.

Two ac sources are developed in the above manner, and the loads are divided so that a complete loss of either source will not interrupt cable power. The alternator for each source is provided with an identical emergency unit running at no load. Special circuits automatically transfer to the emergency unit upon failure of the regular set. For long-term repairs, the equipment includes a fifth alternator unit for manual connection to either source to replace any running alternators. Use is made of separate distribution cabinets and cable runs to reduce to a practical minimum the possibility of a loss of both ac sources.

Regular Units

The use of standby equipment extends into the dc plant also. Each cable may be supplied by any one of three dc regulator bays. Normally, two regulators operate in parallel as the source of cable current, with each regulator connected to a separate ac bus. The third regulator bay serves as an alternate for either of the others.

The rectifier and regulating circuits are shown in somewhat more detail in the second schematic drawing. Each regulator bay contains a filtered high-voltage rectifier and two regulating circuits.



Schematic of the power supply for Atlantic cable repeaters. A direct current of 225 milliamperes is carried over the center conductor of the coaxial cable in opposite direction to voice travel.

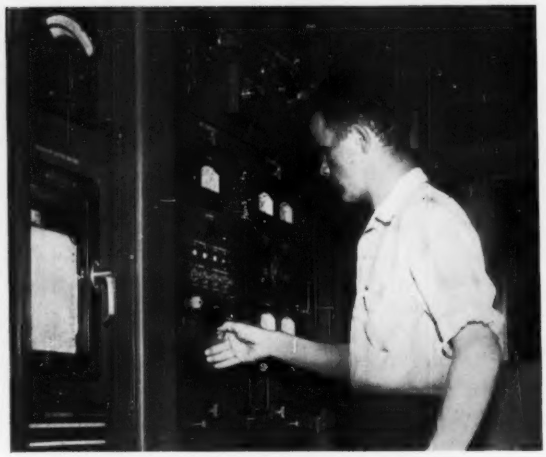
Instantaneous controlling of the current to the common-control bay is achieved with an electronic series tubes regulator circuit. A relatively slow servo system keeps the voltage drop across the series-regulating tubes in the optimum range of current regulation and power dissipation. This system controls a variable autotransformer, which supplies ac power to the rectifier unit.

The Servo System

Current to the cable passes from the rectifier through the series-regulating tubes shown in the schematic, and through a current-sensing resistor in the common-control bay. The resulting voltage drop across the resistor gives a monitoring signal to the regulator bay (or bays) supplying the current. Any change in this voltage is amplified in the dc amplifier portion of the constant-current regulator circuit, and is applied as a change in grid potential on the series-regulating tubes. These tubes act as a variable impedance between the rectifier and the common-control bay. For example, if the cable current tends to increase — because of ac bus variations or earth potential effects — the increase in voltage drop across the sensing resistor results in an amplified increase in grid bias on the regulating tubes. This effectively increases the impedance of the tubes, causing a greater voltage drop to develop across them (plate-to-cathode), which restores the cable current toward the original value. The series tubes seen in the last schematic are capable of absorbing the full rectifier voltage in the event of a fault on the cable or in the common-control bay.

The action of the electronic regulating circuits achieves an output impedance of about 125,000 ohms when the plate-to-cathode voltage of the series tubes is near the nominal 300-volt operating point. That is, if the series-tube voltage changes 50 volts to compensate for an earth potential, the resulting change in the cable current is approximately 0.4 milliampere. At plate potentials below 200 volts, however, the supply impedance drops off rapidly. For plate potentials above nominal, the supply impedance becomes progressively higher, but the amount of power dissipated in the tubes eventually becomes excessive. The servo system was needed to keep the plate voltage of the series tubes within the narrow limits necessary to meet the requirement of the current regulation under normal operating conditions. It also prevents excessive dissipation of power in the tubes during times of large earth potentials or in the event of a load fault.

The plate potential of the series tubes is monitored by means of the control winding of a saturable reactor whose principal winding forms one leg of an ac bridge in the ac control circuit. In the drawing we note that the control winding of a two-phase servo motor is connected across the corners of the bridge; this motor is geared to the autotransformer that supplies ac power to the high-voltage rectifier. The bridge is balanced and the motor is inactive when the series-tube voltage is within about 25 volts of the nominal value. Larger variations change the impedance of the saturable reactor and thereby unbalance the bridge to the extent that the servo motor drives the autotransformer until the plate potential of the series tubes is restored to about 300 volts. In the event of a cable fault, the servo system can drive the autotransformer from maximum to zero output in less than 2 seconds.



H. B. Burton, Eastern Telephone & Telegraph Co. tester, adjusting the autotransformer handwheel in a regulator bay at Clarenville. Part of the associated common-control bay can be seen at left.

Emergencies

The servo motor may be disabled and the autotransformer operated manually. Such operation is required during periods of power turn on, or when the cable voltage at the two terminals is being balanced. The circuit is also arranged for turndown, on an emergency basis, under automatic control of the high voltage and high-current protection circuits in the common-control bay, or by manual operation of a switch.

Output of the regulator bays, together with the cable and the transmission path, are brought together in the power-separation filter of the common-control bay. The cable current-sensing

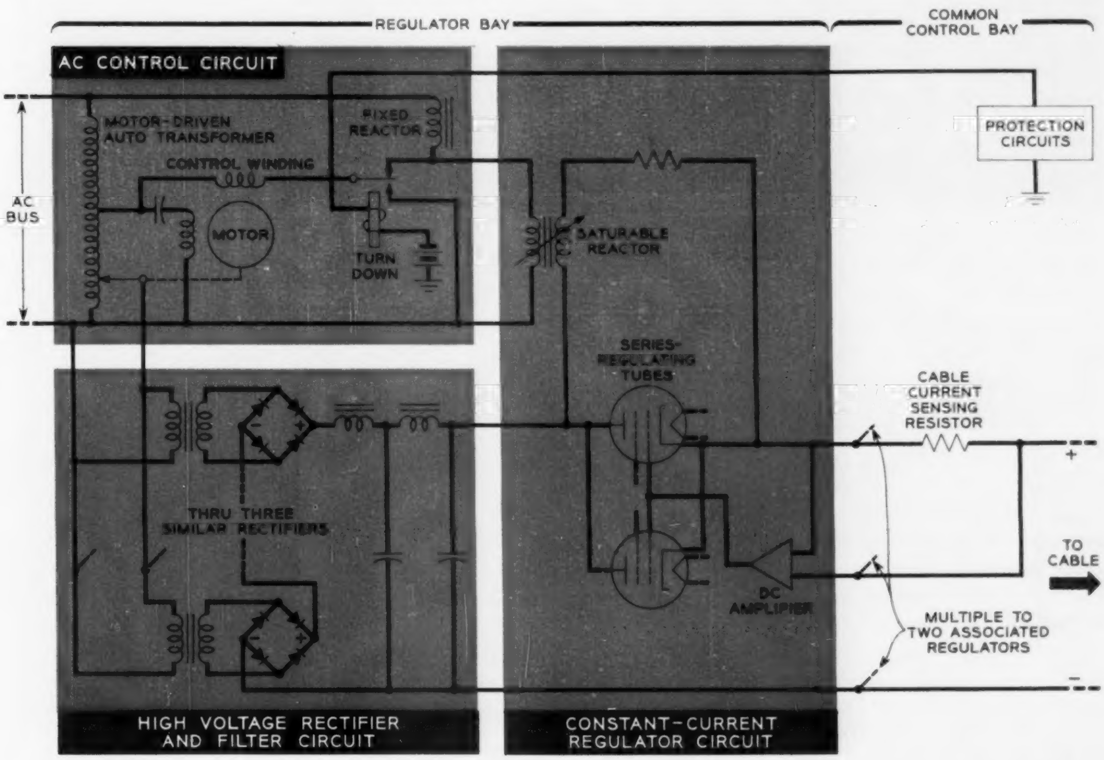
resistor and the protection and alarm circuits are also located in the common-control bay. Several magnetic amplifiers are used to monitor the cable voltage and current while giving insulation between the high-voltage circuitry and the control apparatus. The magnetic amplifiers are three-winding devices. One winding monitors the cable voltage (or current), a second supplies an insulated signal to the relays of the alarm and protection circuits, and the third provides a means for calibrating the relay circuits without disturbing the cable current and voltage.

Protection and Convenience

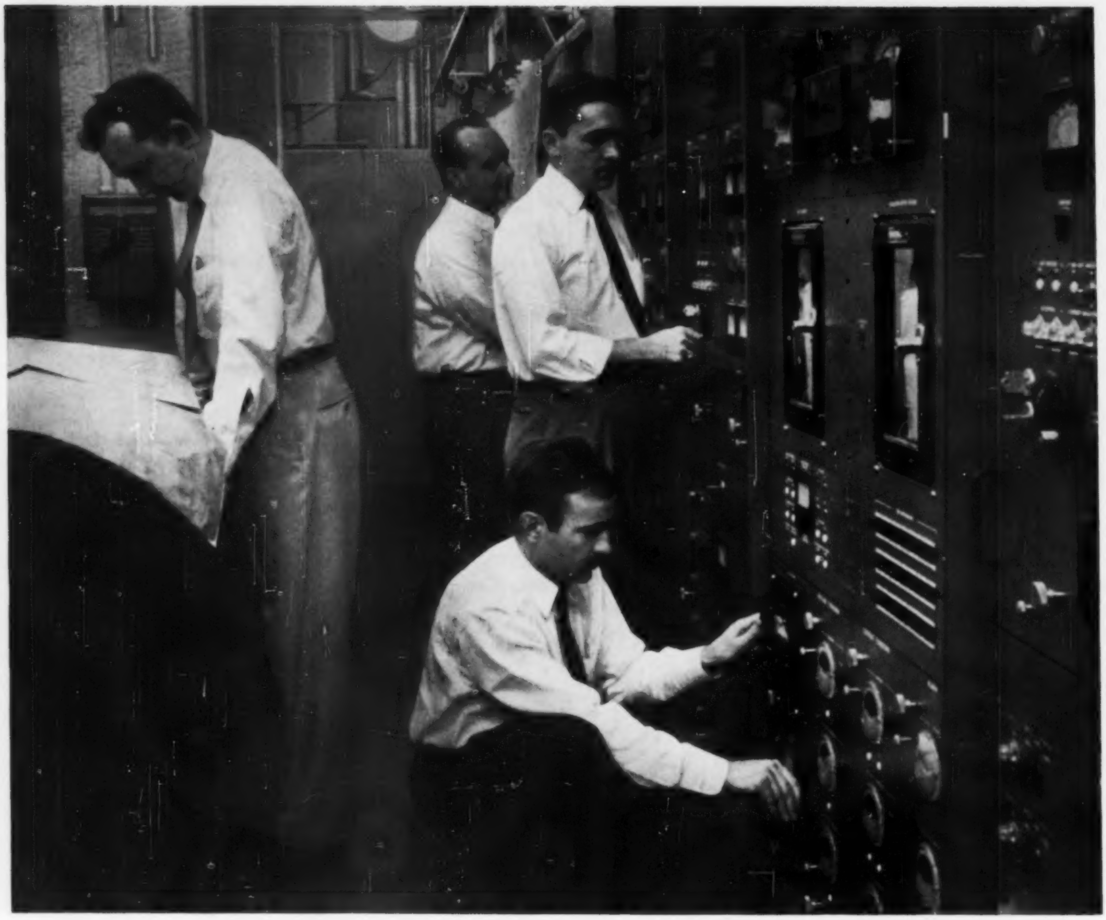
In the event the cable current exceeds the desired value by more than 5 per cent, or the power-supply voltage exceeds 2600 volts, the protection circuits act through the ac control circuits of the regulators to reduce the regulator outputs to specified limits. False operation is avoided by requiring that two out of three magnetic amplifiers and associated relay circuits are in agreement. Alarms are given when the cable current deviates from the nominal value by more than plus or minus 2 per cent or the cable voltage by plus or minus 5 per cent. Alarms also indicate the failure of an ac bus or a regulator bay, and faulty operation of a protection circuit relay. Finally, three separate 24-volt distribution sources are used in the alarm and protection circuits so that failure of any one source will not result in false alarms or loss of cable protection.

A test unit for adjusting the relays of the protection circuits is included in the common-control bay. Precision meters to indicate the cable current and voltage are furnished; recording instruments keep a continuous record.

The dominant features of the equipment design of the dc plant are the use of pull-out type units for ease of maintenance, and an elaborate key interlock system to protect people from dangerous voltages and to prevent interruption of cable power. To remove either regulator from service, it is necessary first to connect the spare regulator to the cable as a replacement. However, before access can be had to the test compartment of an out-of-service regulator, the output of



Schematic of the rectifier and regulating circuits. Each regulator bay contains a filtered high-voltage rectifier and two regulating circuits; autotransformer powers rectifier unit.



Author, V. F. Lopresti, A. H. Evans, and J. K. Mills (l to r), engaged in the rigorous testing of the power plant for the transatlantic cable. The equipment functioned before cable laying.

its autotransformer must be adjusted to a safe potential. To open the high-voltage compartment of the common bay, it is necessary to ground the cable through the cable-shorting switch.

Power in Advance

Actual need for suitable power supplies preceded the laying date of the first cable by several months. DC power plants were installed in the cable factories in both America and England. This was necessary to permit measurements on the cable itself, under power, and on the repeaters spliced into the cable at about 37-mile intervals. A dc power supply was also required on board the cable-laying ship. In conjunction with the power supply at the land end of the cable, this equipment made it possible, for measurement purposes, to power the cable during laying operations. Power was turned off only during the intervals necessary to splice the cable at the end of each 200-mile "ocean block."

To meet the schedule commitments, it was necessary to manufacture the dc plants in the Bell Laboratories New York City location. For test purposes, a substantially complete system was put into operation using two simulated transatlantic cables. Data was obtained on transients created at various points in the simulated cables, and "basic training" afforded for the personnel of the Laboratories, Long Lines, and the British Post Office who were to operate the system on board ship and in the land terminals.

Since the installation of the transatlantic cables, similar power supplies have also been used in the cable systems connecting the United States with Alaska and Hawaii. A second system to Europe is now being installed, and a Puerto Rican system planned.

NEWS

Low-Melting Glasses for Encapsulating Electronic Devices

A new group of glass compositions that melt at low temperatures has recently been developed by S. S. Flaschen, A. D. Pearson, and W. R. Northover of the Metallurgical Research Department at Murray Hill, N. J. These compositions have far-reaching implications in the manufacture of moisture-sensitive devices.

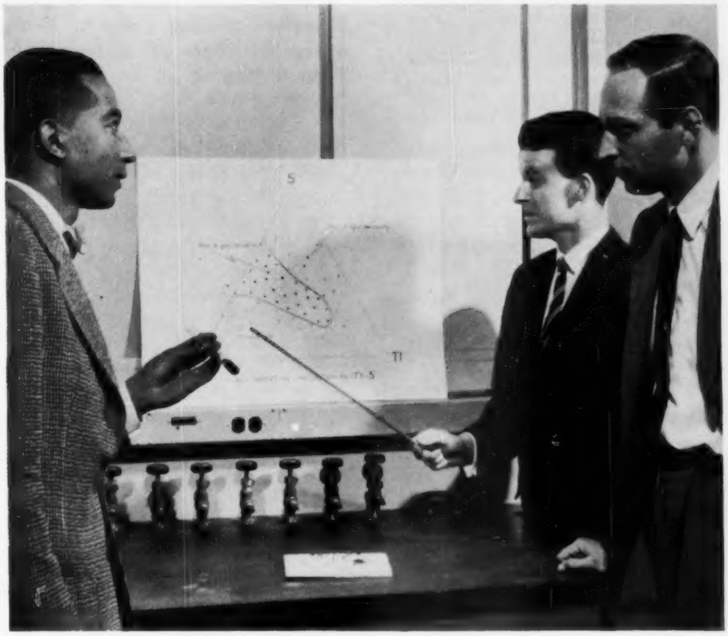
Composed of varying proportions of sulfur or selenium, and the heavy metals arsenic and thallium, the glasses become very fluid at temperatures between 125 and 350 degrees C—a range 300 to 400 degrees C below that at which any previously known glass has melted. In this temperature range their viscosities are approximately equal to that of castor oil at room temperature. Such a viscosity makes it suitable to coat devices by a simple dipping procedure.

Electrically, the glasses range from semiconductors to insulators. Chemically, they show the same durability characteristics as glasses in general. They are insoluble in water, dilute alkalis, acids including hydrofluoric acid (which does affect common glasses), and organic solvents. They are attacked, however, by concentrated alkalis. Several compositions are stable in air to above 250 degrees C.

The compositions exhibit extremely low permeability to both water and helium, and possess good wetting, or adherence, characteristics with respect to most metals. Such properties are not normally found in organic coating materials. These low-melting glasses are also unusual in that they can be evaporated and condensed as thin glass films. Compositions containing selenium bond particularly well to ceramics and to the silicate glasses.

The development of these materials has opened new possibilities of encapsulating semiconducting devices, capacitors, resistors and printed-circuit boards. It appears that in most cases, proper choice of composition, design and processing can circumvent the difficulties that might arise from differences in thermal expansion at very low temperature values.

Laboratories engineers are presently studying the practicability of coating semiconducting devices with these low-melting glasses. In experiments with silicon diodes, for example, they have obtained excellent initial characteristics. In addition, they have observed improvements when such units were heated or operated.



W. R. Northover, left, A. D. Pearson, center, and S. S. Flaschen discuss early phase diagram of chemistry of low-melting glass.

H. K. Dunn Honored By Miami University

H. K. Dunn, of the Visual and Acoustics Research Department, was recently honored by Miami University in Oxford, Ohio, on the occasion of the school's sesquicentennial year. He was named one of seven outstanding graduates in physical science.

Mr. Dunn received a silver medal encased in plastic. The award was made on May 7 at the opening session of a symposium on "Energy and Its Social Implications," which was held at Oxford.

Dr. Fisk to Head Newark College Research Foundation

The trustees of Newark College of Engineering announced on May 26 the names of fifteen men who will serve as the Board of Directors of a newly-established Newark College of Engineering Research Foundation. Dr. Edward F. Weston, chairman of the college board, stated that eight of the directors are closely related to the college in one capacity or another, and seven are representatives of industry and the professions. Dr. J. B. Fisk will serve as chairman of the board.

Under the terms of the agreement established between the college and the directors of the foundation, the college will retain responsibility for operation of research and the fulfillment of research contracts. The college's faculty committee on research will screen faculty research proposals and recommend the use of funds.

The foundation has as its three main objectives: (1) creating opportunities for the professional development of the teaching staff of Newark College of Engineering by providing its members with broadly fundamental research activities in science and engineering; (2) attracting capable young engineering graduates to the engineering teaching profession by offering them a combined program of education, teaching and research; and (3) developing programs at the college to assist secondary school teachers of science and mathematics in their own professional advancement.

W. H. Martin Retires From Army Department Post

W. H. Martin, former Vice President of Bell Laboratories, recently retired from government service, which he entered upon leaving the Laboratories in 1954. On May 25 a reception and review was given in his honor by the Secretary of the Army in Washington, D. C.

Mr. Martin in 1954 was appointed Deputy Assistant Secretary of the Defense Department, and a year later became the first civilian director of Research and Development for the Department of the Army.

In 1911 Mr. Martin joined the A.T.&T. Co. for transmission work in the engineering department. He continued transmission studies after transferring to Bell Laboratories in 1934, and became Assistant Director of Transmission Development in 1935. He became Director of Switching Research in 1937.

Fabian Bachrach

W. H. Martin

From 1940 to 1944, Mr. Martin was Director of Station Apparatus Development, becoming Assistant Director of Apparatus Development and Director of Station Apparatus in 1944. In 1949 he became Vice President in charge of station apparatus and outside plant development, quality assurance and design engineering.

Among Mr. Martin's engineering projects were the design of transmission systems, long-line facilities and systems that were forerunners of today's radio and television network broadcasting.

I. V. Williams Elected To Board of A.S.T.M.

I. V. Williams of the Metallurgical Research Department has been elected a director of the American Society for Testing Materials. His election, one of six posts filled, was announced at the Society's annual meeting held the week of June 22 in Atlantic City, New Jersey.

Dr. Kelly Accorded Recent Honors

Dr. M. J. Kelly, former President of Bell Laboratories and Chairman of the Board of Directors until his retirement in February, recently received a number of honors and delivered two addresses on the role of science and science education in modern society.

During June, Dr. Kelly received two honorary doctorate degrees — an Honorary Doctorate of Science from Case Institute at Cleveland on June 4, and an Honorary Doctorate of Engineering from Princeton on June 16. At Case Institute, he was the Convocation Speaker, and addressed the graduating class on the subject, "The Nation's Need for Your Dedicated Service."

An additional honor was accorded Dr. Kelly on June 13 when he received the Alumni Medal from the University of Chicago. This medal is awarded for distinguished service and for contributions in a specialized field by alumni of the University. Dr. Kelly received the Ph.D degree in Physics from the University of Chicago in 1919.

On May 13, Dr. Kelly was elected a Fellow of the American Academy of Arts and Sciences. Also, he recently spoke before the American Society for Engineering Education. His talk, entitled "The Need for Change in Engineering Education," was delivered in Pittsburgh on June 16.

113 Students Receive C.D.T. Certificates

Certificates for completing the three-year Communications Development Training Program were awarded to 113 Members of the Technical Staff at graduation exercises held on June 22. Vice President H. W. Bode presented the certificates in Arnold Auditorium at the Murray Hill location of the Laboratories.

Dr. Gordon S. Brown, dean of the School of Engineering at M.I.T., addressed the class on "After This Commencement — What Next?" Dr. J. B. Fisk welcomed the graduates and guests and introduced the speaker. S. B. Ingram, Director of Education and Training, presided.

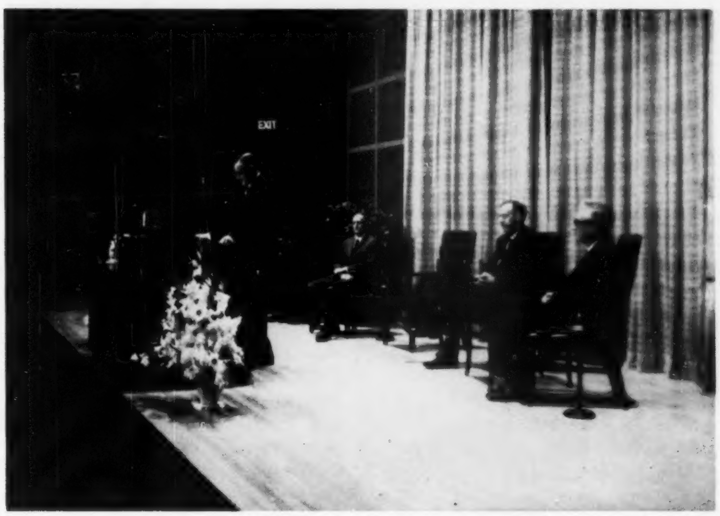
Two Win Fellowships

Dr. Fisk awarded C.D.T. Fellowships to W. B. Macurdy of the Switching Engineering Department and W. C. Ridgway of the Military Systems Studies Department.

The Fellowship winners may work toward Ph.D. degrees while receiving full Laboratories salary and benefits. The awards are given in recognition of excellent work in the C.D.T. Program and in anticipation of the candidate's promise as a Member of the Laboratories Technical Staff.

Mr. Macurdy received his A.B. and M.S. degrees from Dartmouth in 1955 and 1957, the year he joined the Laboratories. He obtained a master's degree in electrical engineering at N.Y.U. last month. He plans to study control systems engineering at M.I.T. for his doctorate.

Mr. Ridgway received a B.S.E. degree in electrical engineering from Princeton in 1957 and a master's degree in the same field from N.Y.U. last month. He has been with the Laboratories since 1957. For his doctorate, he expects to study self-organizing systems in the digital computer field.



M.I.T.'s Dr. Gordon S. Brown, left, addressed C.D.T. graduating class of 113 members. Dr. J. B. Fisk (to right of the speaker), H. W. Bode and S. B. Ingram also participated in the program.

Army Inspection Team Checks Progress of Nike Hercules Equipment

New equipment for use in the Nike Hercules guided missile system was recently inspected by representatives of the Army Ordnance Missile Command at the Whippany, N. J., location of Bell Laboratories. The new features will mean a significant increase in the system's capability for target acquisition and tracking.

This latest member of the Nike missile family is being developed by the same Army-industry team responsible for earlier Nike systems, which have added materially to the nation's defenses. The principal contractors include the Western Electric Company, the Laboratories and the Douglas Aircraft Company.

Some 150 representatives of the Army and associated industrial firms participated in the meeting. In addition to holding technical discussions, the participants evaluated operating equipment on display. This demonstration highlighted the ability of troops to operate the complex Nike equipment successfully.

Color Television 30 Years Old

Thirty years ago last month Bell Laboratories gave the first public demonstration of color television. On June 27, 1929, in a laboratory at the West Street location, a picture was sent from one side of a large room to the other.

Not much bigger than a postage stamp, the picture contained easily discernible color — the American and British flags, flowers, a watermelon and a woman's dress. The event followed public displays of black-and-white TV held the two previous years.

C.D.T. Students Awarded N.Y.U. Master's Degrees

On June 10, ninety-seven Laboratories engineers received master's degrees in commencement exercises at New York University's campus in New York City. The degrees were awarded for completion of the two-year advanced study program in the N.Y.U. graduate center at the Murray Hill, N. J., location of Bell Laboratories.

The N.Y.U. program includes the first two years of the three-year Communications Development Training Program. The third year will be devoted to courses in areas of specific interest to the Bell System.

The N.Y.U.-Bell Laboratories graduate center was opened in the fall of 1957. This class is the first to receive degrees under the cooperative program.

Contents of May 1959 Bell System Technical Journal

The May 1959 BELL SYSTEM TECHNICAL JOURNAL contains the following articles:

Probability of Error for Optimal Codes in a Gaussian Channel, by C. E. Shannon.

Analysis of Phonon-Drag Thermomagnetic Effects in n-Type Germanium, by C. Herring, T. H. Geballe and J. E. Kunzler.

Stabilization of Silicon Surfaces by Thermally Grown Oxides, by M. M. Atalla, E. Tannenbaum and E. J. Scheibner.

Analysis and Design of a Transistor Blocking Oscillator Including Inherent Nonlinearities, by J. A. Narud and M. R. Aaron.

Hall Effect Devices, by W. J. Grubbs.

An Appraisal of Received Telephone Speech Volume, by O. H. Coolidge and G. C. Reier.

J. B. Fisk, W. O. Baker Speak at Symposium On Basic Research

J. B. Fisk and W. O. Baker, Vice President—Research, spoke at a symposium on basic research recently held at the Rockefeller Institute in New York City. The symposium was sponsored by the National Academy of Sciences, the American Association for the Advancement of Science, and the Alfred P. Sloan Foundation.

On May 15, Dr. Fisk spoke on "Basic Research in Industrial Laboratories."

"First and most obviously," he said, "basic research leads to the acquisition of new scientific knowledge of direct relevance and importance in the company's field of activity. Second, it places the company in a position to recognize, understand and use new discoveries in the industry's field of interest. Third, it aids in long-range future planning, and fourth, it provides a source of personnel for top development jobs.

"The conscious setting of objectives," Dr. Fisk continued, "does no violence to basic research. Basic research is the search for new fact and understanding," he noted. "Because in an industrial setting the scientist's research is relevant to the main aims of the over-all organization, it need be no less basic and no less a contribution to science.

"However," he added, "basic research should be organizationally autonomous. There is much to be gained by the close physical proximity of development and research, but one must not be responsible to the other if each is to do its job."

The important elements of a research environment are certain freedoms, according to Dr. Fisk. These include freedom of choice of problems — subject to the criterion of relevance, and freedom to carry a study to the point of demonstrating the merit of an idea — and to drop it there and go after the next good idea. A third freedom industry should recognize is the freedom of a scientist to publish the results of his research. Communication of knowledge is a responsibility of scientists. Secrecy is undesirable and very seldom necessary, he said.

Dr. Baker on May 14 talked on "The Paradox of Choice," which he defined as the research scientist's choice between doing exactly what his interests impel him to do and what some large part of society might seek to have done.

"A scientist," he said, "has to live with an ever present paradox. To be imaginative, he must be free; but to merit the support of society he has to submit to discipline. A proper understanding by planners, leaders, voters and thinkers of the limits of knowledge and of the uncertainty of it can make the definitions of goals and of the specific aims of industry, government and the public welfare acceptable to the intellectual satisfactions of the basic research scientist," he stated.

Great new bold ideas, comparable to those which have developed in physics, must be sought in the biological and social sciences, Dr. Baker observed. At present, "there is hardly a case where a guiding theoretical precept is established."

Dr. Baker called for the development of a unifying theory, or theoretical framework on which to hang the bits and pieces of biological information. This, he claimed, will demonstrate once more that science is constrained to one particular path toward a desired objective.

In support of his thesis, Dr. Baker cited the development of the transistor. Government and industry desperately wanted facilities beyond the vacuum tube, but they were found, not by looking for the transistor, but by following theoretical leads on the behavior of electric charges in a crystal medium.

HIGH-TEMPERATURE ELECTRICAL INSULATION

Many potentially important applications of electrical circuitry at high temperatures are presently hindered by the lack of wire insulation that can stand the heat. But recent discoveries at Bell Laboratories indicate that this hindrance may be overcome. S. S. Flaschen, of the Metallurgical Research Department, and P. D. Garn, of the Chemical Research Department, have shown that fluoride coatings can be formed on copper, aluminum, and other metal wires to provide exceptionally high insulation values at elevated temperatures. The coatings are flexible and free from porosity.

In a paper presented at a meeting of the American Ceramic Society on May 19 in Chicago, Illinois, Messrs. Flaschen and Garn described how the insulating coatings are formed directly on freshly cleaned copper or aluminum by exposing them to oxidizing carriers of fluorine, such as hydrogen fluoride or elemental fluorine, at temperatures from 300 to 600 degrees C. The thickness of the resulting copper fluoride and aluminum fluoride films depends on the temperature at which they were formed, the concentration of fluorine and the time of exposure. For example, aluminum forms a fluoride film one micron thick in a few minutes at 500 degrees C. These films adhere to the metal even when the specimens are bent repeatedly at 90 degree angles.

Electrical insulation values are very high for both copper and aluminum films. The resistance of films 1 to 2 microns thick may be as much as 10^{11} ohms at room temperature. They retain their excellent insulating properties at high temperatures. For example, aluminum fluoride films exhibit resistances of about 7×10^{8} ohms at temperatures as high as 500 degrees C. The aluminum fluoride films also show excellent resistance to oxidation even above 600 degrees C. And they show no tendency to hydrate or dissolve on exposure to high humidity.

In contrast to the new development, the best organic insulating coatings cannot be used continuously above 300 degrees C. Moreover, other inorganic insulators are generally porous and non-flexible, although some may be used as high as 830 degrees C. On the other hand, the insulating fluoride coatings should be satisfactory almost up to the melting point of the conductor.

This new approach to insulating could provide the answer to some of the problems encountered in missile re-entry and guidance systems, as well as in more earth-bound applications of high-temperature electronics.

S. S. Flaschen, left, and P. D. Garn inspect a strip of aluminum, coated with the new electrical insulation. This insulation is formed by exposing aluminum or copper shapes to oxidizing carriers of fluorine.

Dr. J. B. Fisk Receives Honorary Doctorate

Dr. J. B. Fisk at Commencement exercises of Newark College of Engineering where he received the honorary Doctor of Science degree on June 4th. At center is Dr. R. G. Cowan, Treasurer of Board of Trustees, who presented Dr. Fisk for the degree. At right is Dr. E. F. Weston, Chairman of the Board, who conferred degree.

Dr. J. B. Fisk received the honorary degree of Doctor of Science on Thursday, June 4, at the 43rd commencement exercises of Newark College of Engineering. He is the ninth person to receive the degree since the college first granted honorary doctorates in 1919.

In conferring the degree, Dr. Edward F. Weston, chairman of the N.C.E. Board of Trustees, cited Dr. Fisk as a physicist, industrial leader, and government adviser, saying that "Newark College of Engineering is honored to bestow upon you, inspirer of others, esteemed scientist and citizen, the degree of Doctor of Science."

In addition to the N.C.E. degree, Dr. Fisk holds honorary doctorates from Carnegie Institute of Technology (1956) and Williams College (1958). He is a member of the National Academy of Sciences, a fellow of the American Physical Society, the American Academy of Arts and Sciences and the Institute of Radio Engineers. He was formerly a senior fellow of the Society of Fellows at Harvard, and is a member of a number of other scientific and professional groups.

Chemistry, Physics On TV "Continental Classroom" Next Fall

Continental Classroom, the first network television program for college credit, will present a new course—Modern Chemistry—during the 1959-60 academic year. The program, to be taped in color, will be telecast five days a week from 6:30 to 7:00 A.M. It will be carried by most stations in each time zone over the National Broadcasting Company network, beginning September 28th.

Sponsors of the second year-long course will be the American Chemical Society and N.B.C. Financial backing will be provided by the Bell System, the Ford Foundation, and five other leading industrial organizations.

The national teacher of Modern Chemistry will be Dr. John F. Baxter, professor of chemistry and head of the general chemical division of the University of Florida. The course will consist of a study of the fundamental principles of chemistry and a survey of recent developments.

Atomic Age Physics, the 1958-59 offering on Continental Classroom, received nine distinguished awards, including the Sylvania and Peabody Awards, during the program season. The program was cited by various organizations for its pioneering in national educational TV, as well as for its contributions to America's scientific learning.

The physics program will be rerun during the coming academic year. These telecasts will be seen from 6:00 to 6:30 A.M. on most N.B.C. stations in each time zone.

Compatible Stereo From Bell Laboratories Featured on Radio

A Laboratories development for transmitting compatible stereo sound over two radio channels was featured last month by two radio shows. The system permits the full stereo effect without sacrificing the quality of the program for the single-channel listener *(see April 1959* RECORD).

On Sunday evening June 14, New York City radio station WQXR devoted substantial time to musical selections in compatible stereo on its "Adventures in Sound" show. The program's director also interviewed F. K. Becker of the Systems Research Department, inventor of the system. The two following Sunday night programs also contained sections of compatible stereo broadcasting.

In addition, the N.B.C. network used Laboratories-designed circuits during the entire week of June 15-19 on the afternoon "It's Network Time" broadcast. Delayed broadcasts were also scheduled by many N.B.C. affiliates. The show features Skitch Henderson in a live musical variety and guest format. It was carried in compatible form over a network of 15 stations.

Contents of July 1959 Bell System Technical Journal

The July 1959 BELL SYSTEM TECHNICAL JOURNAL contains the following articles:

Research Model for Time-Separation Integrated Communication, by H. E. Vaughan.

Variable-Length Binary Encodings, by E. N. Gilbert and E. F. Moore.

Recurrent Codes: Easily Mechanized, Burst-Correcting, Binary Codes, by D. W. Hagelbarger.

Representation of Switching Circuits by Binary-Decision Programs, by C. Y. Lee.

A Method of Coding Television Signals Based on Edge Detection, by B. Julesz.

Equilibrium Delay Distribution for One Channel with Constant Holding Time, Poisson Input and Random Service, by P. J. Burke.

Evaluation of Solderless Wrapped Connections for Central Office Use, by S. J. Elliott.

Bell System Science Films Receive Honors

Several of the television film programs comprising the Bell System Science Series recently received a number of honors. The science series consists of one-hour long color films on various scientific subjects. The programs are designed to dramatize the role of science in everyday life and to evoke the interest of young people in scientific careers. In addition to their television showings, they are widely distributed in schools.

On May 6, the Television Academy of Arts and Sciences presented its "Emmy" for the best cinematography for television to Ellis W. Carter, director of photography on "The Alphabet Conspiracy." Mr. Carter was also director of photography on "Gateways to the Mind."

At the tenth annual National Film and Filmstrip Awards held May 8 in New York City, *Scholastic Teacher* Magazine presented certificates to "The Strange Case of the Cosmic Rays" and to "The Unchained Goddess." The two films were selected as "outstanding" films for grades 3 through 12. A nationwide panel of audio-visual educational experts made the selections.

"The Strange Case of The Cosmic Rays" also won the Bronze Skull of the Caribou at the Venice Film Festival, it was announced in April. The film was one of 27 in the informational film division submitted for judging by the Department of Audio Visual Instruction of the National Education Association. Of the 27, only two won awards.

Ocean Cable Laying Interrupted by Fire Aboard Cable Ship

Fire broke out on the cable ship *Ocean Layer* on June 14, and thus interrupted laying operations for the second transatlantic telephone cable system. At the time the captain gave the order to abandon ship, the west-east link of the two-cable system had reached a point about 600 miles from Penmarch, France. All aboard — including nine Long Lines men and F. J. Herr of the Transmission Development Department at Bell Laboratories — were picked up by a German ship, the *S. S. Flavia.*

The east-west cable of the system was completed earlier this summer. After making a final splice off Newfoundland, the cable ship *Monarch* began laying the west-east portion, extending it to a point about 666 miles east of Clarenville. Here, the *Ocean Layer* took over and had covered most of the eastbound route. At the time of the fire, the ship had laid all but 33 miles of the cable on board. She was to start laying the final length in July.

The *Ocean Layer* was scheduled to reach Penmarch by late July. The summer laying program is being rearranged, and negotiations are under way to secure the aid of other cable ships in helping the *Monarch* to complete the year's commitments. It is expected that this will be possible with little delay in the scheduled service dates.

The new cable system will be the second across the Atlantic and the first to link North America and Europe directly. The earlier transatlantic system — between Newfoundland and Scotland — began service in 1956.

Underwater telephone cables are free from the interference that periodically affects overseas radio circuits. They have been made possible by the design of special cable structures and repeaters, carefully manufactured to ensure long operational life in the rigorous ocean environment.

TALKS

Following is a list of speakers, titles, and places of presentation for recent talks presented by members of Bell Laboratories.

ACOUSTICAL SOCIETY MEETING, Ottawa, Canada.

Anderson, O. L., and McSkimin, H. J., *Determination of the Equation of State of Solids by Ultrasonic Methods.*

Barney, H. L., Haworth, F. E., and Dunn, H. K., *A New Artificial Larynx*, (Presented by Dunn, H. K.).

Bömmel, H. E., and Dransfeld, K., *Excitation Detection and Applications of Hypersonic Waves.*

David, E. E., Jr., see Mathews, M. V.

Dransfeld, K., see Bömmel, H. E.

Dunn, H. K., see Barney, H. L.

Flanagan, J. L., and Guttman, N., *Pitch of Periodic Pulse Without Fundamental Component.*

Guttman, N., see Flanagan, J. L.

Hanson, R. L., *Sound Localization.*

Haworth, F. E., see Barney, H. L.

Mathews, M. V., and David, E. E., Jr., *On Signal Detection, Signal Perception and Ideal Observers.*

McSkimin, H. J., see Anderson, O. L.

McSkimin, H. J., *Performance of High Frequency Barium Titanate Transducers for Generating Ultrasonic Waves in Liquids.*

Schroeder, M. R., *Improvement of Acoustic Feedback Stability in Public Address Systems.*

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Logie, J. R., *The Nike Hercules Guided Missile System,* First Presbyterian Church, Mendham, N. J.

Loomis, T. C., *What is Emission Spectrometry — What Can It Do?* Engineering Institute: Industrial Applications of X-Ray Diffraction Techniques, U. of Wisconsin, Madison, Wis.

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Morton, J. A., *Impact of Military Science and Technology on Economic Security,* Worcester Polytechnic Institute, Worcester, Mass.

Morton, J. A., *Challenge, Motivation and Reward in Science,* Annual Lehigh Valley Science Fair, Allentown, Pa.

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Pollak, H. O., *Mathematical Research in the Communications Industry,* Rutgers University, New Brunswick, N. J.

Raspanti, M., see Keister, W.

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Schawlow, A. L., *Superconductivity,* R.C.A. Laboratories, Princeton, N. J.

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Terry, M. E., *Polynomial Curve Fitting on Electronic Computers,* 13th Annual Convention of the American Society for Quality Control, Cleveland.

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Wasserman, E., *Thermochromism of Bianthrone,* Washington University, St. Louis, Mo.

Williams, H. J., *Magnetic Domains in Single Crystals and Thin Films,* N. J. Chapter, American Society for Metals, Newark, N. J.

PATENTS

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THE AUTHORS

W. D. Lewis ("The Idea of Time Sharing") joined the Radio Research Department of the Laboratories at Holmdel in 1941. Until 1945 he was concerned with radar research and later with research on microwave filters, light-route radio relay systems and switching systems. In 1951 he transferred to Murray Hill where he was Director of Switching Research until 1958, when he was appointed Director of Research — Communications Systems. Dr. Lewis is a member of the Overseers' Committee to visit the Division of Engineering and Applied Physics at Harvard. He is a Fellow of the Institute of Radio Engineers, a member of the American Physical Society, of the Association for Computing Machinery, and of the American Association of Rhodes Scholars.

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J. B. Howard was born in New Haven, Connecticut, and lived in that area until completing his formal education. He received a B.S. degree with Honors from the Sheffield Scientific School of Yale University in June 1936, and immediately joined Bell Laboratories, where he is now supervisor of the group responsible for thermoplastics on wire and cable. His work at Bell Laboratories has covered many phases of high polymer chemistry, including studies of the structure and properties of polyethylene, polyesters and polyamides; polymerization techniques for vinyl monomers as well as for polyesters and polyamides; development and application of rubber insulation and jacket compositions; and development of test methods and specifications for plastics and rubber. Mr. Howard is a member of the American Chemical Society, the Society of Plastics Engineers, Alpha Chi Sigma, and Committee D-20 of the American Society for Testing Materials. He is the author of the article "Plastics for Underseas Cables" in this issue.

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Carl A. Dahlbom

F. J. Hallenbeck, a native of New York City, joined the Laboratories in 1923. He was first engaged in work on telephone instruments and then transferred to the Bureau of Publication where he was an editor on the Bell Laboratories Record. After this, he was involved for many years in the development of transmission networks for Bell System and military communication facilities. He is now Systems Development Engineer at the Merrimack Valley location of Bell Laboratories, concerned with the development of broadband carrier systems. Mr. Hallenbeck graduated from the Polytechnic Institute of Brooklyn with the E.E.

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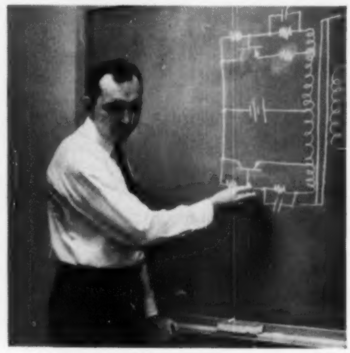
R. E. D. Anderson was born in Minneapolis, Minnesota, and received the B.S.E.E. degree from the University of Minnesota in 1947. He then joined the Laboratories, working first in the trial installation group and later in the toll circuit analyzation group. In 1951 he transferred to Power Development where he has been engaged in circuit design of power rectifiers and regulators. This has included electron tube, magnetic and transistorized power supplies for station systems, teletype and PBX applications, submarine cable systems and several military projects. At present he is primarily engaged in the design of transistorized power supplies for electronic switching. Mr. Anderson, the author of "Power Supplies for the Clarenville-to-Oban Submarine Cables," is a member of Tau Beta Pi and Eta Kappa Nu, an associate member of the A.I.E.E., and a licensed professional engineer in New Jersey.



R. E. D. Anderson

"PACKAGING" MICROWAVES FOR MOUNTAIN TOPS

"TJ" radio-relay station at Black Mesa, Arizona

In Arizona, the telephone company faced a problem. How could it supply more telephone service between Phoenix and Flagstaff—through 135 miles of difficult mountain territory?

Radio offered the economical answer: a new microwave radio-relay system recently created at Bell Telephone Laboratories. Operating at 11,000 megacycles, it was just right for the distance, and the number of conversations that had to be carried.

But first other problems had to be solved: how to house the complex electronic equipment; how to assemble and test it at hard-to-reach relay stations way up in the mountains; and how to do it economically.

On-the-spot telephone company engineers had some ideas. They worked them out with engineers at the American Telephone and Telegraph Company and at Bell Telephone Laboratories. The result: a packaged unit.

The electronic equipment was assembled in trailer-like containers at convenient locations and thoroughly checked out. The complete units were then trucked up the mountains and lifted into position.

The system, now operating, keeps a watch on itself. When equipment falters, a relay station switches in stand-by equipment, then calls for help over its own beam.

The new Phoenix-Flagstaff link illustrates again how Bell System engineers work together to improve telephone service. Back of their efforts is the constant development of new communications systems at Bell Laboratories.

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